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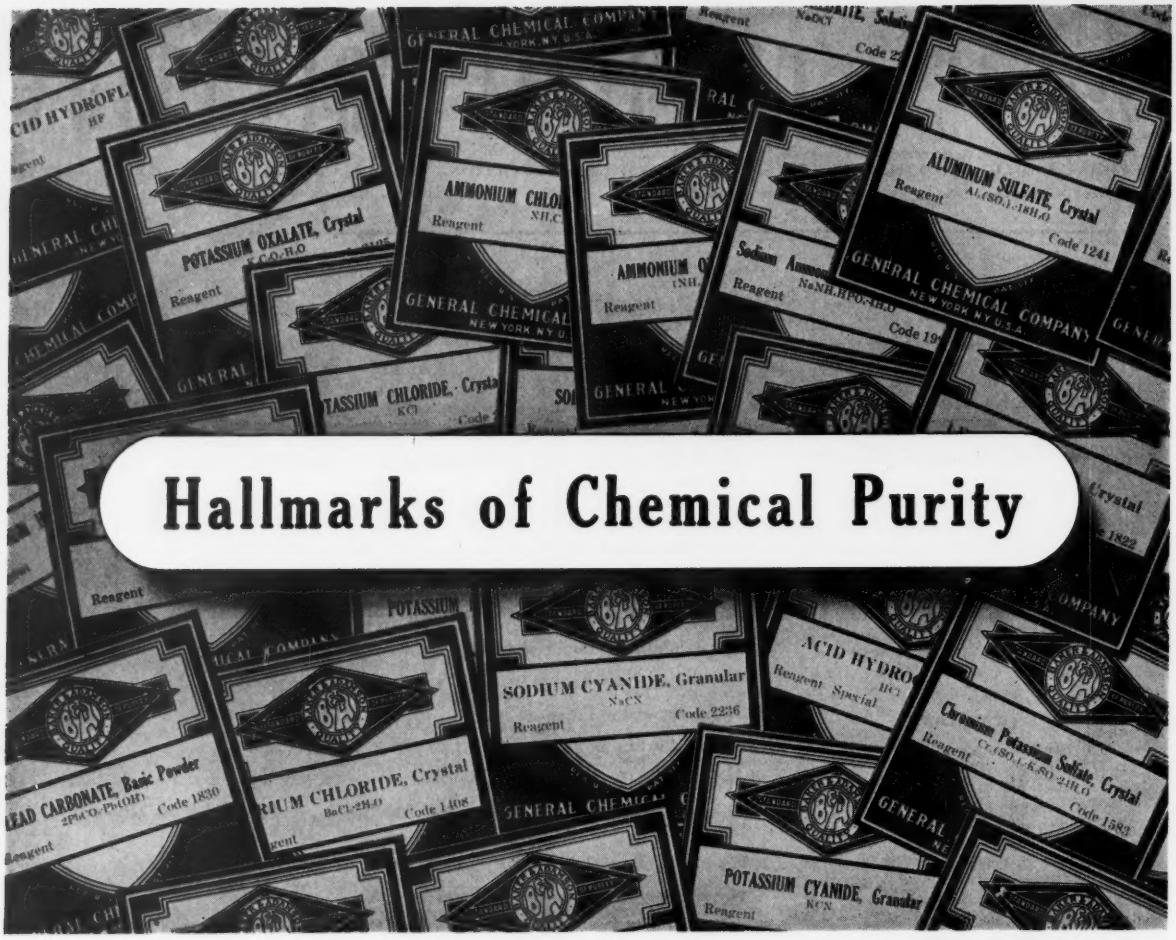

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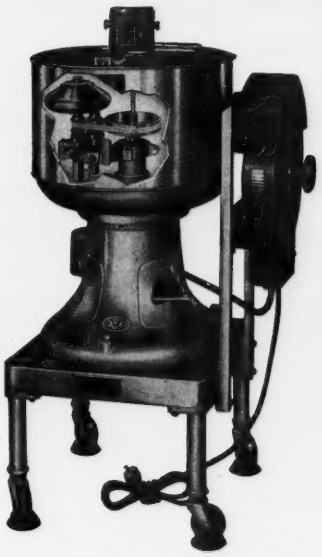

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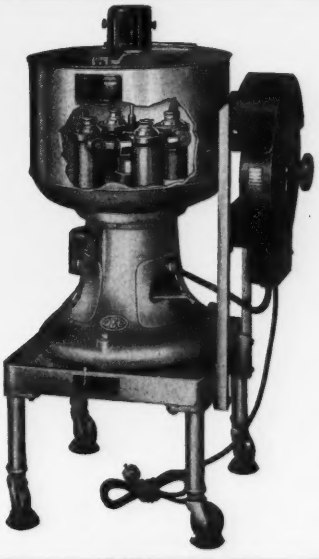

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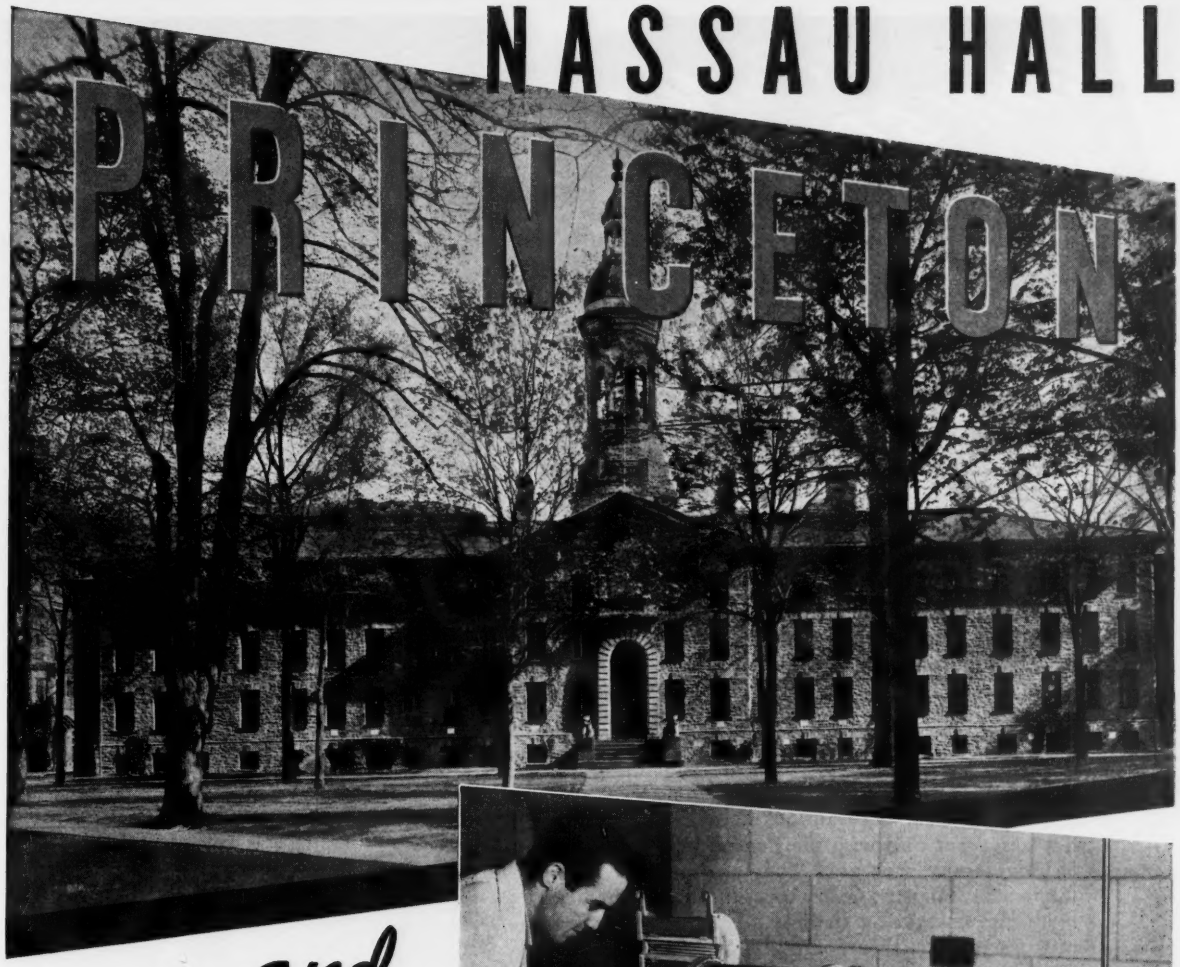

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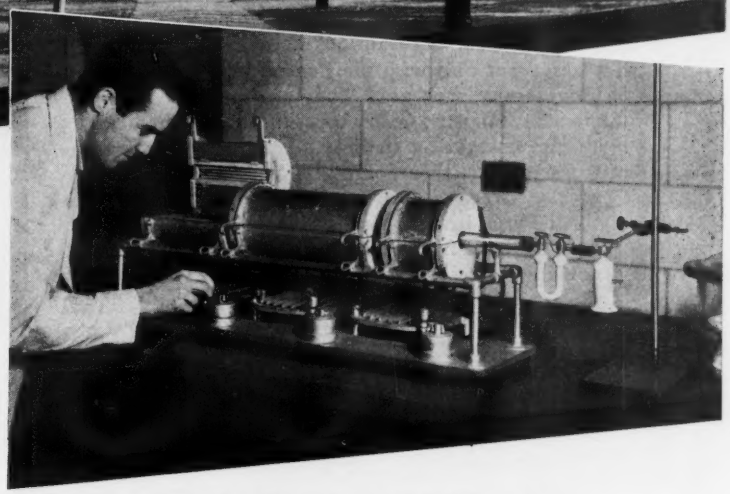

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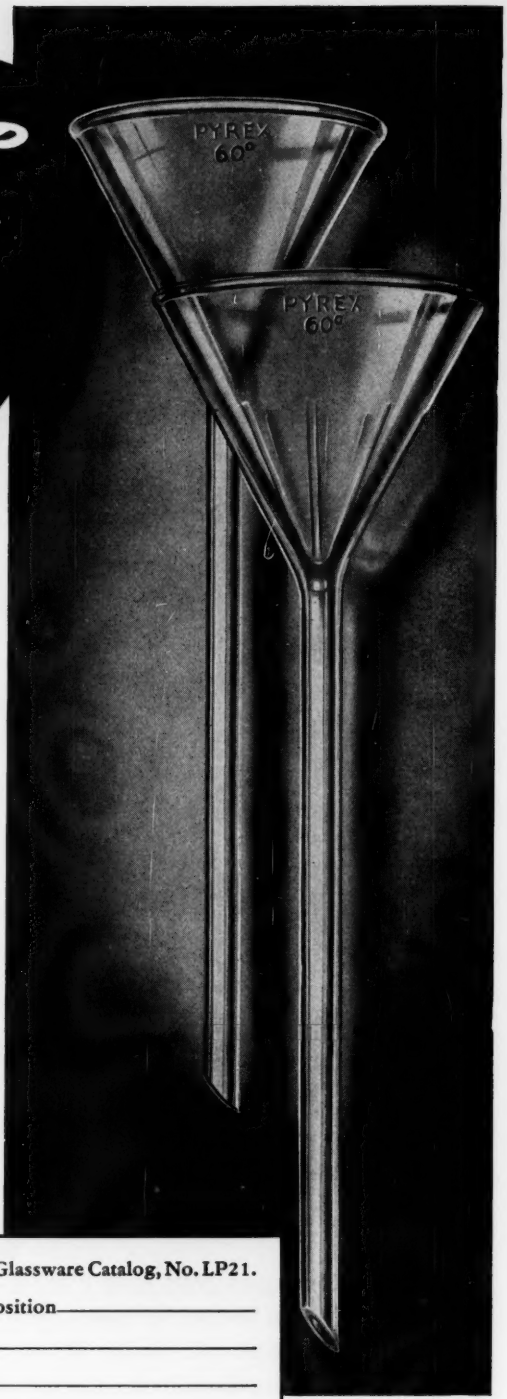

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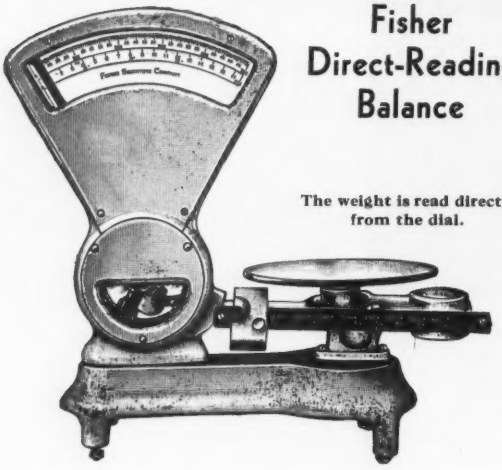

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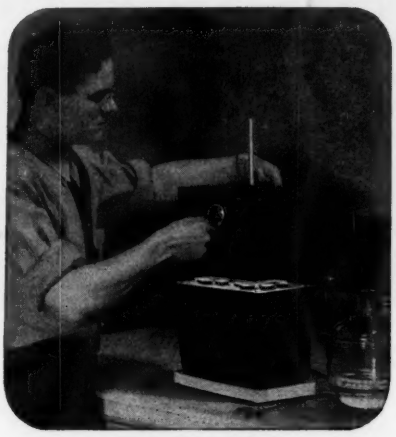

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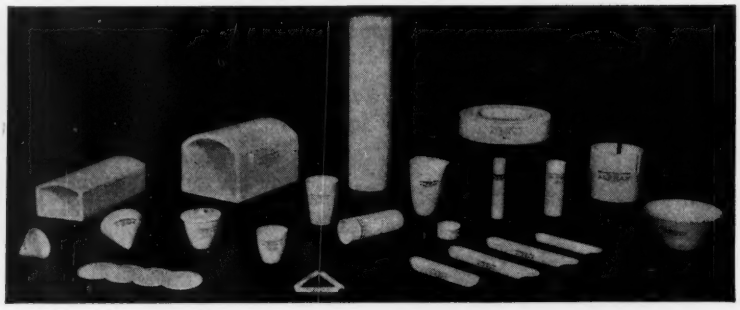

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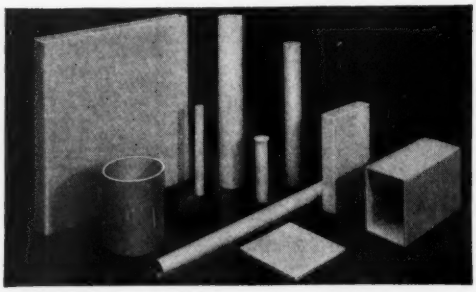

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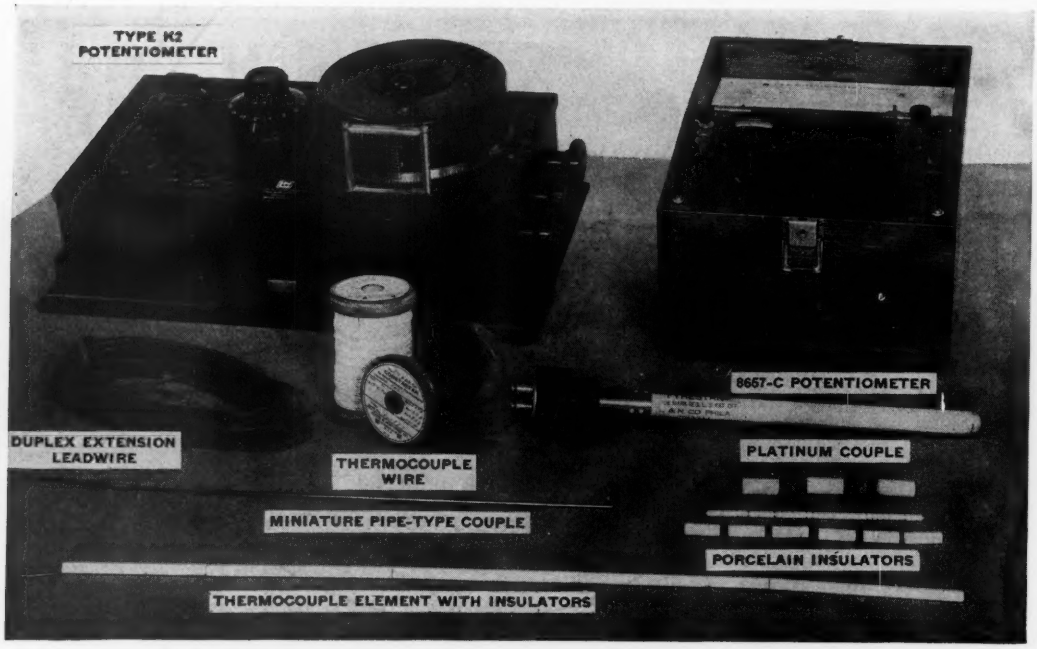

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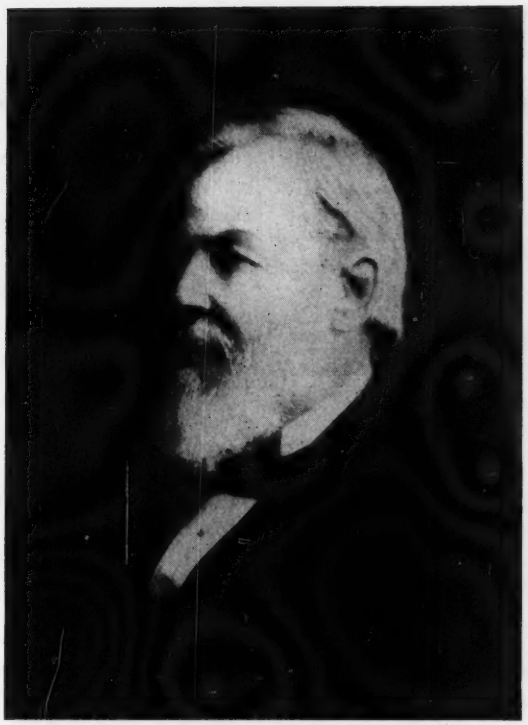

Courtesy of the College of Charleston

Lewis Reeve Gibbes (1810–94)

(For further information see the article, "Lewis Reeve Gibbes and the Classification of the Elements," by Wendell H. Taylor, on page 403.)

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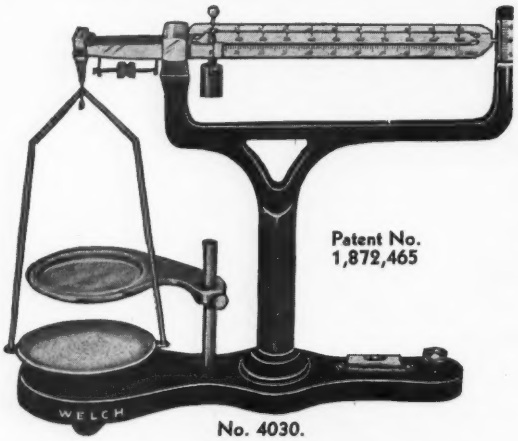

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Editor's Outlook

YOU can't build a house without a hammer and saw —at least. Nor can you make a chemist without the proper tools, supplies, and equipment. But unless something is soon done about it there seems to be a good chance that we will have to *try*.

To many people the stringency of materials means tossing their broken aluminum pans into a pile on the village green, but this is only the "outward and visible sign." Priorities regulations dog our footsteps only less diligently than the tax collector. And suddenly a situation has developed which has a serious bearing upon the whole field of chemical education.

Many of the items on the purchasing lists of our chemistry departments are subject to priority control. The defense industries are given the first call on such things as acetone, ether, methanol, magnesium, zinc, aluminum, and other metals, to say nothing of instruments, tools, and special apparatus. In many cases the manufacturer is not permitted to sell unless the purchaser has a high "priority rating." And even in case he is permitted to do so, he is reluctant, since an instrument maker under such circumstances, for example, would not be allowed the raw materials to replace the article sold. Consequently, the instrument maker is discouraged and the colleges and universities are put at a disadvantage. Since becoming aware of this situation we have been making some quiet inquiries and hope later to make the results known.

If still true, this is a sad state of affairs. For how are our institutions to turn out well-trained chemists if they are not to be allowed the materials and equipment with which to do the job? Even amid all the confusion it seems to be clear that a continuous supply of trained chemists is as important as that of the actual munitions of war.

There is plenty of evidence that the responsible elements in the government have a high regard for the strategic importance of chemists, as a class. The letter from the Director of the Selective Service System, which was reproduced in our June issue and which brings this point to the attention of local draft boards, is particularly good evidence.

Then there is the establishment of the Engineering, Science, and Management Defense Training program which provides for *special* courses of training for chemists (as well as engineers and others). Since it is not intended that these special courses shall supplant or interfere with the *regular* training of chemists the importance of the latter activity is merely emphasized.

Very well then, trained chemists are necessary for the national defense. But how are you going to have them if you don't provide adequately for their training? No one supposes that flying cadets can be trained for the Air Force without a sufficient supply of basic training planes. Similarly, our colleges and universities cannot supply chemists unless they are permitted to purchase enough magnesium to teach them how to carry out a Grignard synthesis; or enough analytical balances to give them practice in gravimetric analysis; or the electrical and optical instruments which will enable them to carry out the technics of their profession in efficient and modern fashion.

Many of our universities are carrying on chemical "projects" of a defense nature. These are being given every encouragement and consideration and some of them may indeed yield results of extreme importance. We would submit, however, that the professional training of chemists is as much of a defense activity as any specific project for which a university may have contracted and deserves fully as much consideration. In some cases the regular function of the institution is sorely pressed to supply the personnel for the special defense work.

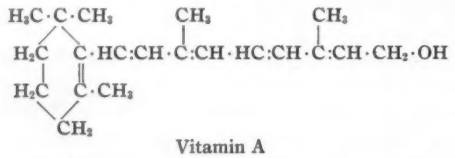
Inquiry has shown that a number of colleges and universities have been hampered in their work of professional training of chemists by their inability to get materials such as those mentioned above. We cannot think that the quantities involved for educational purposes are large enough to justify any concern in the greater production program. We think it is high time, however, that institutions concerned with professional chemical education get together to present their case to the necessary authorities, in the hope that the latter can find some reasonable way in which the unfortunate situation can be remedied.

Steps have already been taken, we understand, to provide priority for both industrial and educational research. While this will help the graduate schools materially it is not a recognition of the principle for which we are arguing. Who turns out the magnesium, the aluminum, the sulfuric, nitric, and acetic acids, the methanol, the acetone, and the rubber, for which there is such a cry? *Chemists*. And who turns out the chemists? Our colleges, universities, and technical schools. If the results of chemical research are important, how much more important it is to produce the men who produce the results!

(*Continued on page 417.*)

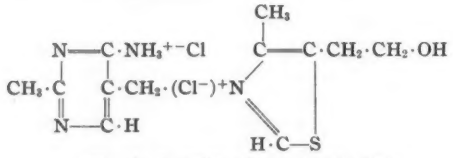
What's Been Going On

In the Chemistry of the Vitamins



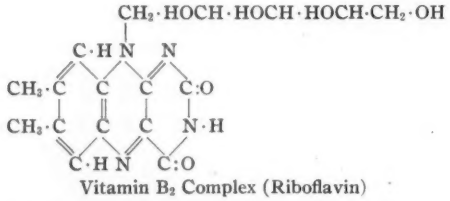
Vitamin A

VITAMIN A is recognized as an essential factor in the maintenance of the integrity of the epithelial tissues. Deficiency results in abnormal keratinization of tissues, xerophthalmia, night blindness, and other disturbances. Three naturally occurring carotenes are precursors of vitamin A, the *beta*-carotene yielding two equivalents of vitamin A. By use of molecular stills, concentrates of vitamin A are now being prepared commercially by fractional vacuum distillation.



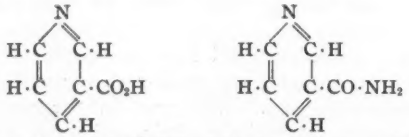
Vitamin B_1 (Thiamin hydrochloride)

Vitamin B_1 appears to be essential for the normal functioning of the nervous system and the gastro-intestinal tract. It is used in the treatment of beriberi, and acts as an appetite stimulant. It is now being produced synthetically. It is soluble in alcohol and water.



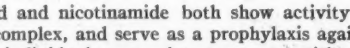
Vitamin B_2 Complex (Riboflavin)

Riboflavin is a part of the vitamin B_2 complex, and is thought to be essential to the normal functioning of the motor, sensory, and central nervous systems. It is slightly soluble in water, sparingly soluble in phenol, amyl acetate, and cyclohexanol, but insoluble in acetone, benzene, chloroform, and ether.



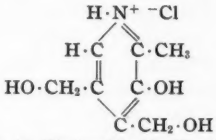
Nicotinic acid, m.p. 235°–7°C. Nicotinamide, m.p. 129°–31°C.
Vitamin B_2 Complex (Nicotinic acid and Nicotinamide)

Nicotinic acid and nicotinamide both show activity similar to vitamin B_2 complex, and serve as a prophylaxis against pellagra. Certain individuals respond to treatment with nicotinic acid by flushing of the face, itching, and burning of the skin, whereas nicotinamide does not produce these undesirable disturbances and appears to be just as effective otherwise.



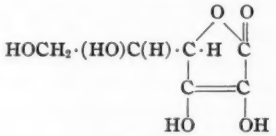
Vitamin B_2 Complex (Pantothenic acid)

Pantothenic acid has been known as the *filtrate factor* of vitamin B_2 complex. Experimental studies have demonstrated that it prevents dermatitis in chicks and growth failure in rats, but its therapeutic role in human nutrition is still unknown. Pantothenic acid is usually isolated as its calcium salt, m.p. 198°–200°C.



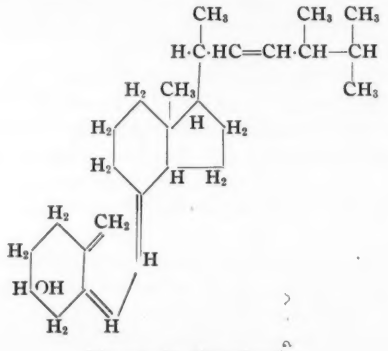
Vitamin B_6 Hydrochloride (Pyridoxine)

Pyridoxine, another factor of the vitamin B_2 complex, has been established as of some importance in nutrition, particularly in deficiency diseases. It is sparingly soluble in acetone, but is soluble in both alcohol and water.



Vitamin C (Ascorbic acid)

Vitamin C is used as a prophylaxis and in the treatment of scurvy. It appears to be essential to the maintenance of sound bones and teeth, and aids in bodily resistance to toxins and infections. It is produced synthetically from either sorbose or xylose. In the formulation shown here, the group to the right of an asymmetric grouping is believed to be below the plane of the page, whereas the group to the left is above the plane of the page, with all other groups in the plane of the page.



Vitamin D_2 (Calciferol)

Vitamin D_2 is formed following irradiation of ergosterol, 7-dehydrocholesterol, and other sterols. It is available commercially as *viosterol*, but is not produced synthetically. It is stable to acids, alkalies, heat, and oxidation. It is soluble in fats and oils, but insoluble in water.

The vitamin D or anti-rachitic group may include as many as twelve or more different substances which exert anti-rachitic activity. One of the more important ones is believed to be D_3 which is formed in human and animal bodies when the skin is exposed directly to sunlight or ultra-violet light.

The D group is essential to normal bone growth and tooth development, since these factors aid in controlling the calcium level of the blood and the metabolism of both lime and phosphorus.

(*Continued on page 448.*)

Lewis Reeve Gibbes and the Classification of the Elements

WENDELL H. TAYLOR

Princeton University, Princeton, New Jersey

LEWIS Reeve Gibbes, Professor of Chemistry at the College of Charleston from 1839 to 1892, stands alone among American chemists of his generation by virtue of his valuable and original speculations on the classification of the chemical elements. The present paper pays belated tribute to a man who, though handicapped by isolation in a small southern college and experiencing the privations which followed the Civil War, nevertheless arrived independently at many of the conclusions reached a few years earlier by the founders of the Periodic System.

At no time since Gibbes' first presentation of his ideas has justice been done him, and mischance and neglect have combined to render his work practically unknown. Between 1870 and 1874 Gibbes worked out the first version of his "Synoptical Table of the Chemical Elements" and in October, 1875, discussed an improved form of it at a meeting of the Elliott Society of Charleston, in whose *Proceedings* the paper (*1*) was duly scheduled to appear. But within a month the difficulties of the reconstruction period had obliged the Elliott Society to suspend all activities and for more than ten years Gibbes' contribution lay unpublished. Only in 1886 did the "Synoptical Table" and its explanation reach a public which had long since ceased to need it. Since that day little attention has been paid to Gibbes' scheme. The single previous account of it is that given by Venable (*2*) who presents it briefly and somewhat in the light of a curiosity, without much attempt to assess its virtues and defects. Venable's reproduction of the table contains several errors and is open to criticism. The present account seeks greater fairness to Gibbes by presenting his classification against the background of those which it was intended to supplant; for if the "Synoptical Table" is to be compared at all with the generalizations of Lothar Meyer and Mendeleeff, it must be with their original schemes (*3*) of 1868 and 1869, respectively. These relatively crude arrangements—and not the Periodic Table as we know it today—were their authors' first answers to the question which Gibbes asked independently in America: What is the "natural" grouping of the chemical elements?

Since the speculations of Prout and Döbereiner in 1815–17, chemists had sought an underlying connection between mass and the other properties of atoms. While certain family relationships soon became clear, any comprehensive attempt at ordering the elements in a natural system based on mass was, until 1860, doomed to failure because of the inconsistent values of atomic weights current before that time. Only after the new chemistry of Gerhardt, Cannizzaro, and Stas—to name but a few—had provided a revised table of atomic weights did the way stand open to the discovery of the Periodic Law. Gibbes, writing in 1874–75, was aware of the important revisions of atomic weights for these had soon found their way across the Atlantic, but of classifications he knew only the early and imperfect ones of Gladstone (*4*), Cooke (*5*), Odling (*6*), and Dumas (*7*).

The extent of Gibbes' knowledge of other contemporary workers may now be considered. Venable refers to the "presumptive" evidence of Gibbes' complete ignorance of the Periodic Law and the work which led up to it. This evidence, consisting of Gibbes' apparently full citation of such published work as was known to him and the unlikelihood of his bringing forward his own imperfect classification had he known of the advances made in Europe, is much strengthened by the following considerations. In 1860 Gibbes already foresaw (*8*) the difficulties which scholars would experience in the approaching Civil War, especially in the matter of access to scientific journals. He may not have foreseen the disruption of academic life during the War itself, which involved the temporary dispersal of students, faculty, and library (*9*), and rendered scholarly work impossible for several years. Even on the resumption of normal activities in 1866, financial problems remained to harass the college and its faculty, and this is reflected in a letter written much later by Gibbes to his Board of Trustees (*10*). Though the college had never supplied scientific periodicals, he says, he had in former years bought many himself which "in later times" he had found himself unable to do. Thus the entire decade during which the Periodic Law was gradually emerging from the work of Newlands, Lothar Meyer, and Mendeleeff was for Gibbes one of chaos and deprivation. We cannot be surprised, therefore, that of the twelve literature references cited by Gibbes in his paper of 1875, only three are to publications of later date than 1860, and of these two are to the 1863 and 1868 editions of Watts' "Dictionary of Chemistry." It may be noted that only in the second supplement to this (1875) did its first account of Mendeleeff's work appear, while Gibbes' principal periodical source of information, the *Chemical News*, first carried a brief account of the Periodic Law in the issue of December 24, 1875. Needless to say, no such account had yet found its way into any of the standard texts, so that the originality of Gibbes' paper can hardly be doubted.

Figure 1 is a photograph of Gibbes' table as it ap-

peared when finally published. How great an improvement it was upon the disconnected tables of atomic weights, electrochemical affinities, and valencies, which alone served to correlate the properties of the elements in American texts of 1870–74 can best be appreciated by following Gibbes' own account of his intentions and veloped in modern Chemistry." To do this, he assembled the well-known families of elements, one below another, on parallel lines numbered from minus four through zero[2] to plus three, to correspond with the principal valence of each group. In each of these horizontal lines the elements were written in order of their

TABLE OF CHEMICAL ELEMENTS.

a	SERIES. A	B	C	D	E	F	G	H, I	K	GROUPS.
−4		C=12	Si=28	Ti=50			Sn=118			Silicon Gr.
−3		N=14	P=31	V=51.3	As=75	Cb=94	Sb=122	Ta=182	Au=196.6	Phosphorus Gr.
−2		O=16	S=32	Cr=52.5	Se=79	Mo=96	Te=128	W=184	Os=199	Sulphur Gr.
−1		F=19	Cl=35.5		Br=80		I=127			Chlorine Gr.
0										
+1	Li=7	Na=23	K=39		Rb=85	Ag=108	Cs=133		Tl=204	Kalium Gr.
+2	Gl=9.3	Mg=24	Ca=40	Zn=65	Sr=87.5	Cd=112	Ba=137		Pb=207	Calcium Gr.
+3	−B=11								Bi=210	
	Al=27.5——Cr=52.5 ; Mn=55 ; Fe=56 ; Co=59 ; Ni=59 ; Cu=63.5——U=120									Iron Gr.
	Y=61.7			Zr=89.5; Ce=92 ; La=92 ; D=96				Er=112 ; Th=115.7		
	In=74				Ru=104; Ro=104; Pd=106——Pt=197 ; Ir=197					Platinum Gr.
	H=1 Hg=200									

FIGURE 1.—GIBBES' SYNOPTICAL TABLE (1875)

procedure in drawing it up. The name, "Synoptical Table," which he gave to his new scheme indicated his primary intention to display in a single chart as many as possible of the several types of relationships existing among the elements. He was well aware that, to obtain the advantages of a single table, some of those inherent in the customary separate tables must be lost, chief among these sacrifices being the abandonment of the linear form of the electrochemical series. But this was a minor disadvantage in the classification which should depict in one and the same table: "1. The Groups of Elements, as at present recognized. 2. The Atomic Weights of each Element, as now adopted. 3. The Character of each, as Perissad or Artiad.[1] 4. Their Atomic equivalence or Atomicity, as Monad, Dyad, Triad, etc. 5. Their Electro-chemical character, as Electro-positive or Electronegative." In departing from the customary mode of presentation, Gibbes was wise enough to take his data from a single source, "...to avoid undue bias as to numbers, groups, etc." This source was Barker's textbook (*11*) which he was then using with his class.

Gibbes' approach to the problem of classifying the elements was thus the reverse of that followed by Gladstone, Newlands, Lothar Meyer, and Mendeleeff. All of these workers, seeking for a "natural" system, had arranged the elements in order of increasing atomic weight and the last three men had observed the periodic repetition of properties which led to the detection of the Periodic Law. Gibbes' immediate aim was "to construct a Table to exhibit in the lecture-room a synoptical view of the Elements and their relations as deatomic weights, increasing from left to right. Thus they also fell into vertical columns, or series, in which Gibbes observed "...a remarkable regularity...in the succession of the numbers...yet with gaps unfilled by numbers in several of the groups." Here, in other words, was the regular succession of atomic weights emerging from a system based upon stepwise change in the chemical property, valence.

We must now consider in greater detail Gibbes' arrangement of the elements, and the conclusions which he found it possible to draw. Guided by the order of succession which he had observed, Gibbes made several changes in the arrangement which would have been the consequence of following Barker's tables slavishly. With considerable chemical insight, Gibbes utilized his knowledge of isomorphism and other properties in placing vanadium, columbium, tantalum, chromium, and boron in the pigeon-holes now so familiar to chemists. In this way he placed in the main body of the chart, which corresponds closely with the skeleton of our present short form of the Periodic Table, forty-one of the sixty-three elements known in 1874. Of these, all but five—his Series K—were correctly located, and even where his fragmentary knowledge of some of the heavy elements misled him, Gibbes grasped the correct general outline. Thus:

"...this last series is marked K to indicate this large interval from G, and the intermediate column is marked H, I, to indicate uncertainty as to the number of intervening or missing series, and the probability that there would be at least two..."

[1] Of odd or even valency, respectively. In Gibbes' day much importance was attached to these characteristics, which were wrongly thought to be invariable.

[2] In order to bring as close together as possible those elements having the strongest affinity for each other, *e. g.*, the halogens and the alkali metals. It is impossible to suppose that Gibbes saw any significance, other than a mathematical one, in his line corresponding to zero valence.

The remaining twenty-one elements, all metals with the exception of hydrogen, and including the transition elements and the rare earths, offered greater difficulties, and the fact that in eight cases there were gross errors in the atomic weight values accepted at the time[3] did not make it easier for Gibbes to arrive at a logical arrangement. The best that he could do was to lump all but hydrogen and mercury in a second part of his table, beneath the positive portion of the main part but distinct from it. Here he grouped the twenty recalcitrant metals[4] along lines suggested by analytical and mineralogical similarities. Gibbes' failure to assign aluminum and manganese to suitable empty spaces in the upper portion of the table is striking, and must be explained by his secondary reliance upon atomic weight as a basis of classification. Chemical analogies between manganese and the halogens, and between aluminum and boron, were little recognized at the period in question, and Lothar Meyer's placing of aluminum and manganese in his first table was just as unsatisfactory. Gibbes recognized the inadequacies of the lower portion of his table and with a candor which also goes far to convince the reader of his perspicacity, he remarks concerning a particularly unsatisfactory corner:

"The other two, Er, Th, are written here for a reason, very unscientific indeed, but not without influence, I imagine, in other schemes than the present,—I know not where else to put them. I am not sufficiently familiar with the elements on this line to make a better arrangement."

Hydrogen was given a position at the bottom of the table, incongruously associated with mercury. The latter element was tentatively assigned by Gibbes to its correct place in the calcium group, but owing to the novelty of the implied relationship, as well as the fact that gold (which he had wrongly placed in Series K) had a lower atomic weight, he did not so enter it in his final version of the table.

Despite obvious shortcomings, Gibbes' table succeeds to a remarkable degree in achieving the "synoptical" presentation of chemical relationships which was the objective of its author. It is important to remember that the development of a single relationship amongst all the elements was not uppermost in Gibbes' mind; to him the numerous attempts which had been made in previous years to work out algebraic equations relating all atomic weights seemed, at best, arithmetic or geometric exercises on which undue stress should not be laid. Having devoted much attention to such exercises in which, as an able mathematician, he was remarkably proficient, Gibbes finally remarked:

"The possibility of finding for the numerical series of atomic weights such expressions as above given is not to be overlooked, since these expressions may lead to the perception of new chemical relations, but they must hold a subordinate place until such relations have been brought out."

Similarly:

"...if chemical analogies or relations require large deviations such as the halving or doubling of some of these weights, our arithmetic and geometric structures will give way at once."

We can only regret that to the clarity, prudence, and lack of bias displayed by Gibbes throughout his argument, there could not have been added the greater chemical experience which better facilities would have afforded him.

We have finally to test the value of Gibbes' classification by inquiring what deductions he was able to draw from it. To what extent he was conscious of the periodic relationship implicit in his table is a question not easily decided. Certainly there are no words in his paper of 1875 which can fairly be considered an independent statement of the Periodic Law. Although Gibbes refers frequently to the "regularity" which he observed, the adjective "periodic" does not appear.

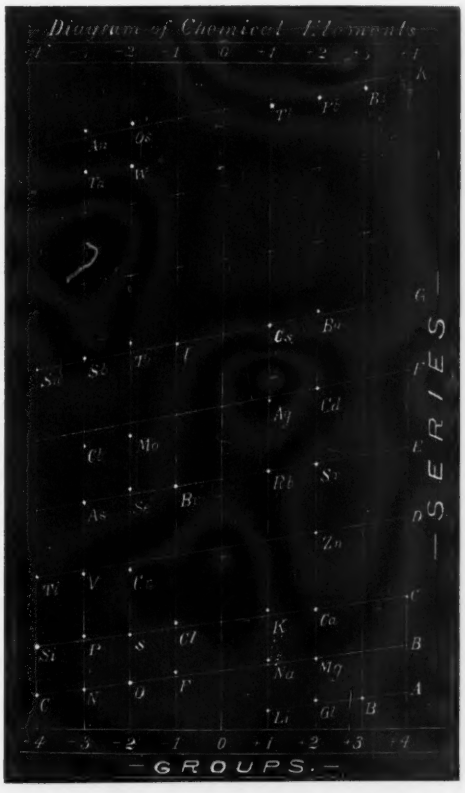


FIGURE 2.—GIBBES' DIAGRAM (1875)

Nevertheless, the diagram (Figure 2) which Gibbes offers as a graphic substitute for the main portion of his table, and still more the Archimedean spiral whose construction he minutely describes to demonstrate the continuity of his series, can leave little doubt that he

[3] Namely for Ce, D, Er, In, La, Th, U, Y; although the equivalent weight had been determined fairly accurately in each case except that of the mixture didymium.

[4] As well as chromium which, though already located above, he wished to show in relation to aluminum, manganese, and iron.

was aware of a unifying relationship between the elements from lithium to barium, based upon recurrence of similar properties with increasing mass. His own words in this connection deserve quoting. They follow the details of the construction of the diagram:

"The points indicating the members of each Series will now be found to lie very approximately on a *right line*, these lines cutting the axis of ordinates at nearly the same angle. The 'parallelism' will now be not only arithmetic but geometric, presented to the eye, and will be most striking in the case of series A, B, C, less so in case of D, E, and F, G, K. Such a diagram may be found useful in instruction. . . ."

Also:

"The remarkable continuity of the three series A, B, and C, permits the construction of another geometric design, less convenient than the last for reference, but allowing the *three* series to be exhibited in continuity as *one*, that is by the use of an Archimedean Spiral whose radius vector increases by 16 units in one revolution."

The construction of this having been detailed, Gibbes goes on to note, somewhat tersely:

"If the diagram of preceding section with rectangular coördinates were wrapped around a cylinder whose circumference equals interval in diagram from +4 to −4, the result just mentioned would be exhibited with the same accuracy, a helix being substituted for the spiral."

Gibbes' helix and spiral correspond to earlier suggestions of de Chancourtois and Mendeleeff, respectively; his diagram anticipates to a considerable extent those of several later authors, including Crookes' (*12*) of 1886.

The detailed prediction of undiscovered elements which was the most striking feature of Mendeleeff's long paper of 1871 (*13*) finds no parallel in the case of Gibbes, but the American chemist took particular note of the blank spaces in his table and, in considering the construction of curves which should correspond to the series of atomic weights, remarked: ". . . it may become worth our while to construct equations for such curves, especially if any of the gaps now existing were filled by the discovery of new elements." He also refers to certain of the blank spaces as corresponding to elements "missing at present." Gibbes' foresight thus contrasts very favorably with the arbitrary procedure of Newlands, whose Law of Octaves (*14*) failed to win the support it deserved largely because of its author's attempt to force all known elements into a rigid scheme in which some places were doubly filled and none left vacant.

Far more interesting is Gibbes' very astute differentiation between the two sub-groups of each family of elements. The existence of these, which had become clear to Meyer and Mendeleeff only with the development of the later forms of their respective tables, is pointed out by Gibbes in every case where his table afforded the necessary groups of elements. He refers to them as the "primary sub-group" (S, Se, Te; P, As, Sb; etc.) and the "secondary sub-group" (Cr, Mo, W; V, Cb, Ta; etc.). An equally compelling proof of Gibbes' chemical insight has never been commented upon. It is his recognition of what we know today as "typical" elements. Mendeleeff had so designated Li, Be, B, C, N, O, F in his paper of 1871, and the name, though often criticized, has been retained. Gibbes' clear ideas in the matter are best shown by his own words:

"Each of the negative members of series B, namely F, O, N, and C, though closely allied to the primary sub-group of their respective lines, is yet so distinctly marked by several characteristics that they may be regarded as forming in those lines each a *third* sub-group (consisting of a single member) for which it may be convenient to adopt some distinctive epithet."

It will be noted that Gibbes not only recognized the distinctive character of the later members of our first "short period" but also appreciated the fact that each bears a closer relationship to what we should call the B sub-group of the family than it does to the A.

Perhaps enough has been said to justify the author's opinion that the obscure paper of Gibbes, despite its belated appearance, must rank as a classic of American chemistry. If little has been known of the "Synoptical Table," even less has been written about its author and his distinguished services to several branches of science. In view of the inaccessibility of biographical material pertaining to Gibbes, no apology is necessary for adding the following sketch of his career. In securing the material for it the author has had the kind assistance of Professor J. H. Easterby, Director of the Library, College of Charleston, and of Professor S. M. Christian of Agnes Scott College, to both of whom grateful acknowledgment is made (*15*).

Lewis Reeve Gibbes was born in Charleston, South Carolina, August 14, 1810, the son of Lewis Ladson Gibbes and Maria Henrietta Drayton. It is of interest that his mother enjoyed some reputation as a botanist. Young Gibbes was educated at the University of Pennsylvania Grammar School (1821–22), at Pendleton Academy, South Carolina, and at the South Carolina College, where he was graduated with first honors in 1829. Intending to qualify as a physician, Gibbes studied medicine at the Medical College of Charleston in 1830 and again in 1835–36, the four-year intermission having been devoted to the teaching of mathematics at his *alma mater*, first as tutor and later as acting professor. However, after taking his medical degree in 1836—he here gave early evidence of his versatility by submitting a prize-winning thesis in French!—Gibbes went to Paris to continue studies which were to become increasingly liberal. The young scientist's interest in natural history prompted him to take to France collections of South Carolina plants and of marine and fresh water shells of the South Atlantic states, which he exchanged with various naturalists abroad. During his stay of more than a year in Paris, Gibbes studied many subjects besides those usually pursued by medical men; he attended, among others, the lectures of Gay-Lussac and Chevreul at the Jardin des Plantes and those of Dumas and Pouillet at the Sorbonne. Dulong was his teacher also, so that the young scholar who returned to Charleston in the autumn of 1837 and was soon appointed Professor of Mathematics and Natural Philoso-

phy in the newly reorganized College of Charleston was well equipped for duties which were to expand into over half a century of devoted labor, on behalf of many causes.

During his long career, Gibbes taught, at one time or another, mathematics, astronomy, physics, chemistry, and mineralogy. He was for many years secretary of the college faculty, and to these academic responsibilities were added those of the presidency of the Elliott Society of Charleston from 1856–89, as well as an earlier post as secretary of the American Association for the Advancement of Science. Despite heavy demands on his time, Gibbes published numerous papers in many fields of science, mainly in the *Proceedings of the Elliott Society* and the *American Journal of Science*. Some of these were outstanding contributions to the science of the day, such as his comprehensive revision, in 1850, of the species of *Crustacea* in the various United States collections, to which he added valuable notes and descriptions of new species; also his comparison and discussion of all the observations made in the United States on the transit of Mercury of May, 1845. A few other titles taken at random from a long list will serve to indicate the scope of Gibbes' interests, which were all the more remarkable for the thoroughness and scholarship with which this busy man cultivated them: "Solar and Lunar Eclipses"; "Tabular View of 13 Asteroids"; "On Some Points which have been overlooked in the Past and Present Condition of Niagara Falls"; "Determination of Longitude between Charleston and Washington"; "On a Convenient Form of Aspirator"; "Yucca Juice as an Indicator"; "The Ozonizing Powers of the Portulaca." The "Synoptical Table of the Chemical Elements" was Gibbes' principal essay in pure chemistry.

Gibbes' death occurred in Charleston on November 21, 1894, and was the occasion for comment on his work in leading scientific journals both here and abroad. In conclusion may fittingly be quoted the words of Henry E. Shepherd, President of the College of Charleston (1882–97), who in speaking of Dr. Gibbes said:

"Astronomy was his passion, but he cultivated nearly every phase of our complex modern science, and cultivated none that he did not dignify and adorn. As a teacher he was lucidity itself. He not only taught so that he might be understood by the pupil, but so that he could not be misunderstood. He ever manifested a spirit of absolute consecration to his ideal as a scientist, an insatiable quest of knowledge, undiminished even in the view of death, and respect and reverence for the eternal verities of the Christian faith."

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(13) MENDELEEFF, "Die periodische Gesetzmässigkeit der chemischen Elemente," *Ann.*, VIII Supplementband, 133–229 (1871).

(14) NEWLANDS, "On the law of octaves," *Chem. News*, **12,** 83 (1865).

(15) In addition to the brief account given by EASTERBY, *op. cit.*, the following may be mentioned:

(*a*) DAVIS, Outline sketch in Charleston (S. C.) *News-Courier*, Dec. 19, 1901.

(*b*) LABORDE, "History of the South Carolina College," Columbia, **1859.**

(*c*) PINCKNEY, Obituary article in Charleston (S. C.) *News* and *Courier*, Jan. 26, 1895.

As one unassailable stronghold of handicraft and individual effort, research is vitally dependent on effective personnel selection. Particular emphasis is directed toward personal qualities of the prospective employee, as distinguished from technical ability, which can usually be determined from scholastic and other factual records. Characteristics such as creative urge, receptiveness to new ideas, and intellectual integrity—the ability and willingness to recognize and act upon the implications of facts—are particularly important in the personnel of a department which has so large a part in determining the direction and extent of a company's growth. The ability to plan effectively is perhaps more necessary in the junior members of a research organization than in most comparable functions.

—From the *Industrial Bulletin* of Arthur D. Little, Inc., June, 1941

Symposium on the Teaching of Advanced Undergraduate Courses in Chemistry

The Value of Courses in the Identification of Organic Compounds[1]

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DURING the past twenty-five years laboratory courses in methods of identification have been introduced into many schools. These courses have become increasingly popular both with students and teachers and curricula have been revised in order to permit their introduction. Since the undergraduate curricula are designed to prepare students for positions in chemical industry, high-school teaching, and for advanced graduate work, each course must be of value to the student. It is therefore desirable to pause, review the results, and try to determine just what these courses contribute to the students' training.

Courses in identification are most frequently given in the senior year following a full year's course in organic chemistry. Occasionally the material (or a part of it) is incorporated into the laboratory work of the second semester's course in organic chemistry. The place in the curriculum is determined by the time available, but the first has proved more satisfactory. It is also desirable that the course be an optional or elective one. In this way students not interested in organic chemistry may elect other courses and those who do select the course in identification are those who are so interested that they work hard and learn a tremendous amount of practical organic chemistry. The elective system for senior courses of this type has a very favorable psychological effect and makes for an excellent *esprit de corps*.

Some of the specific ways in which a course in identification contributes to the training of chemists are:

1. It reorganizes the student's knowledge of organic chemistry in a practical fashion. During the first year's work in organic chemistry, compounds are studied in homologous series. In practical work a chemist does not meet organic compounds neatly labeled according to classes. Frequently, the starting materials used in a synthesis are known compounds and the problem is to identify the products of the reaction. This calls for the use of reagents and hence the chemist must know the behavior of many different classes of compounds toward each reagent. The course in identification introduces the student to the useful reagents and helps him to organize his previous knowledge of organic reactions so that he knows what compounds give positive tests.

2. A course in identification shows how reagents are used to detect functional groups and thus contributes a firm background to the structural formulas the student already knows. In elementary organic chemistry time does not permit a complete presentation of the absolute proof of the structural formulas of organic compounds from either an historical or a logical viewpoint. Hence, formulas are frequently given with the simple statement that they represent the best explanation of all the known facts. In the identification course, the student actually hunts for functional groups with reagents and obtains experimental evidence for such structures.

3. The student is required to think and plan his experiments and to exercise judgment in interpreting them. The great difference between courses in identification and most of the other undergraduate courses is that as yet no scheme has been devised which reduces the work to the mere following of directions. At each step in characterizing a compound the student must exercise his own judgment. The student's faculty for careful observation, his ability to make reasonable deductions from experiments, and his cleverness in selecting the proper course of action are all called into play.

4. It calls for careful observation of experiments, correlation of data, and its recording. The student must learn what characterizes a positive test, a negative test, or borderline behavior. After carrying out a series of tests, the results must be considered as a whole. The student learns very quickly that it is dangerous to jump to a conclusion regarding the nature of a compound from a single test. Since there are

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several steps in identifying a compound the data must be written down in the notebook so that all the facts may be surveyed and correlated.

The preparation of the written reports on the unknowns is of great value to the student. Here he scrutinizes his data and really sees that his tests have proved the structure of his compound. This written report also places the emphasis on the *proof* of the identification and not merely on the identification itself. This is a point that should be emphasized over and over again, *i. e.*, it is the *proof* that is worth everything. No credit is given for an identification without proof. Assigning each student different unknowns gives him a feeling of individual responsibility and pride in his identifications. The net result is the development in the student of a proper scientific attitude of mind toward investigating the unknown.

5. It teaches the student the scope and limitation of many common reactions and improves his technic in the laboratory. In elementary organic chemistry very little attention is given to the fact that not all members of a given class or homologous series possess exactly the same chemical reactions. In fact, the emphasis is usually just the opposite. Since the student actually carries out many reactions which heretofore have been only equations written on the blackboard he not only learns how to tell when a reaction actually takes place but also learns the specific utility of the reaction. For example, isopropyl alcohol and *tert*-butyl alcohol both react with acetyl chloride but the first gives chiefly isopropyl acetate and the second *tert*-butyl chloride and acetic acid. Stearyl alcohol reacts with acetyl chloride so slowly at room temperature that it is difficult to decide whether a reaction has occurred.

The laboratory technic of students is markedly improved by courses in identification. By limiting the amount of each unknown the student is compelled to be careful and not to waste chemicals. The amounts called for in most of the tests and preparations of derivatives are such that reasonably good technic is required. For seniors, the usual amounts vary from 0.5 to 5 g. An experienced, trained chemist can, of course, use much less, and procedures and technics for carrying out identifications on a micro scale are indeed being worked out.

6. It requires the student to use the library and become familiar with chemical literature. In order to prepare a list of possible compounds the student must consult not only the usual chemistry handbooks by Hodgman and Holmes, by Lange, by Kempf and Kutter; texts such as Mulliken-Huntress, Kamm, Clarke, Campbell, Middleton, Shriner and Fuson; dictionaries such as Heilbron's, but also Richter, Beilstein, Stelzner and, for recent data, *Chemical Abstracts*. The difficulties involved in finding data on compounds and their derivatives are brought to the attention of the student. He not only learns where to look but realizes that he must plan the steps in the proof of the identification of an unknown so as to use the data recorded in the literature.

7. It indicates the necessity for research and provides an introduction to some of the methods. In his search of the literature, the student finds that there are great gaps in lists of derivatives and thus sees immediately one field for research. He may find two entirely different melting points given by different investigators for the same derivative. The reasons for such occurrences are many; perhaps it is a question of purity, possible rearrangements, isomers, or the method of determining the physical constant. It is good for the student to see that there are differences of opinion and moreover he should see that the solution lies in experiment and not in argument.

For teaching purposes, courses in identification are usually designed for the identification of a previously described compound. In actual research work, an investigator works up his reaction mixtures and separates the pure components. Each of these pure compounds is then subjected to the systematic examination for identification. Certain of these will be found to agree with previously described compounds. The remainder are new compounds and as the result of the class reactions considerable information is therefore available concerning the functional groups and general structure. Application of quantitative methods is then necessary. The point is, the systematic scheme of examination thus followed provides a mode of attack on new as well as known compounds.

8. Finally, one of the reasons why the course in identification has become so popular is that it is a very enjoyable one for both student and teacher. The steps in the identification of an organic compound resemble the sequence of events in a detective story. Each unknown is a murderer, whose previous history and subsequent behavior furnish the chemical detective with a list of clues. These lead to the preparation of a list of suspects, one of whom is convicted by means of a cleverly designed trap—the derivative.

It is obvious that although only 25 to 50 reagents may be used on 400,000 to 500,000 compounds the number of permutations and combinations is very great. Hence, new reactions, new derivatives, and new procedures are constantly being met. There is no monotony—every time the course is taught one meets something new.

DISCUSSION OF THE PAPER

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THIS discussion will be limited largely to three of the special values considered by Dr. Shriner for courses in qualitative organic analysis.

The value which is probably the most important was quite properly placed first. This is the reorganization of the student's knowledge of organic chemistry. For some students such a course is really the first practical organization of this knowledge. In the beginning course in organic chemistry there are of neces-

sity many classes of compounds included. However carefully the teacher emphasizes relationships and logical development of the subject there are so many new series of compounds presented in relatively rapid succession with new formulas and new reactions that it is difficult for even the better students to have the subject matter well classified and organized at the end of the course.

One of the first things taken up in the usual course on the identification of organic compounds is classification based on solubility in a few common solvents. While this is more or less arbitrary and is designed primarily to aid in the process of identification it gives the student an unusual satisfaction to feel that the whole field has been surveyed and the many series classified and placed in some eight or nine groups. The experience may be likened to that of acquiring a road map of a country which had previously been somewhat strange and confusing.

Another value which should be emphasized is the necessity for individual thinking and planning. The course in qualitative organic is one in which memory alone will not suffice. Each unknown is in a sense a little research problem requiring careful observation and a practical use of the student's knowledge of organic chemistry. The student, of necessity, gets quite away from the mere following of directions. For a capable student this greatly increases his confidence and ability to work independently.

The third value is the improvement in laboratory technic and the skill required to work successfully with relatively small quantities of material. In this connection any previous training which the student may have had in semimicro technic will be of advantage. The desirability of good yields and the necessity of careful purification are strongly emphasized. The close correlation between theory and laboratory practice serves to increase interest in the course and to show that a thorough knowledge of the fundamentals of organic chemistry is of practical value. Experience has proved that even though the time required in such courses is considerably in excess of the usual time credit ratio they are among the most popular.

Senior Research[1]

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I THINK we are all agreed that the word "senior" as applied to the four-year college of arts and sciences, or the professional school of chemistry, refers to a student in his final year for the baccalaureate degree, normally his fourth year. Presumably he has followed an organized program of work, which has included certain fundamental or basic courses (English, modern languages, mathematics, one or more natural sciences, etc.), both lecture and laboratory methods of instruction having been employed. It is further assumed that the college senior has had experience in the use of the library and some training in both written and oral expression. Surely the senior of superior mental ability is now ready to begin a little original work of his own (under proper guidance); *i. e.*, he should be ready to begin research.

Research is not so easy to define. The word has been overworked. Some people use it in a very broad way; others restrict it; still others use it loosely, vaguely, or even mystically. Let us first attempt to define it and then see if it appears to fit in with a well-balanced and well-organized program of work for the superior college senior majoring in chemistry. Webster's New International Dictionary defines research as "a searching for something, especially with care or diligence." Another wording of the definition reads: Research is the "careful or critical inquiry or examination in seeking facts or principles." Note that no mention is made of the method or procedure. Evidently we are to use our best judgment in this matter, to be original even in our approach or method. This, I think, is as it should be. Certainly we should not be tied down to a routine procedure in conducting research. The very word connotes originality, ingenuity, variation. We cannot express it by a mathematical equation, although the latter may express our results. And so this leads us to inquire into the possibilities open to us—avenues of approach. It is understood that our senior (or should we now say freshman researcher?) is majoring in chemistry, though, of course, there is no difference in procedure regardless of his chosen field of science. Chemistry being one of the so-called exact sciences, our method should include some means of obtaining quantitative data in support of hypotheses, theories, and laws. Chemistry is also an experimental science and, hence, our method may (and often should) include original observations and measurements. Another source of information is in the published works of others. In other words, the research worker has two sources: the library and the laboratory.

The professor who directs the research of a senior should himself be a research man. Moreover, he should be thoroughly familiar with the problem assigned to the senior; otherwise he cannot appreciate the difficulties encountered by the student, and it will at times be difficult to advise him. Indeed, the student may soon come to know more about his problem than the professor. The research director should have his own field of interest and should so group his research problems that they fit into a planned program; only in this way can he make satisfactory progress. A series of unrelated problems is certainly not satisfactory from a pedagogical standpoint. The scientific results obtained by seniors will be limited, but they should not, and need not, be inconsequential. Even if the professor has only undergraduate students to work with him, he should be able to carry forward a definite and worth-while research program. Of course, the professor may have more than one general field of interest; often he does.

[1] Presented as part of a Symposium on the Teaching of Advanced Undergraduate Courses in Chemistry, sponsored by the Division of Chemical Education at the 101st meeting of the A. C. S., St. Louis, Missouri, April 8, 1941.

But he should not spread his undergraduate senior research students over a diversified field. Each student should be made to feel he is contributing his bit to a larger problem. Indeed, research has been defined as an addition to the sum-total of knowledge. From time to time work will be completed which is worthy of publication.

In discussing research in the undergraduate chemistry curriculum, Professor G. B. L. Smith (*5*) says:

"The director of undergraduate research must be intensely interested in the problems upon which his students are working, and he must be willing to give unstintedly of his time and energy to aid in their solution. He cannot be efficient if he has a number of students working on totally unrelated topics, and I do not think it is possible for him to confine his interest to too narrow a field, for, after all, 'there is nothing so broad as a narrow specialty.'

"In regard to choice of subjects suitable for undergraduate research, it is difficult and probably futile to make any definite suggestions. The teaching activities, previous experience, consulting practice (if any), and general interests of the professor largely will govern this choice of field for research. He cannot, however, hope to make any progress scientifically if he selects small and entirely suitable problems here and there. In the course of a few years he has accumulated merely a 'hodgepodge' of isolated data, most of which are so incomplete as to be almost valueless."

A similar idea is expressed by Professor Emmet Reid (*2*):

"For the benefit of science, and incidentally for enlarging the reputation of the director of the research, it is best for all available forces to be concentrated on one line of investigation, and fortunate is the professor who can plan the parts so that they will fit into an important whole and yet leave place for originality and freedom in the fabrication of the parts.

"There is another consideration; the student who has done his dissertation on a small problem, which he can comprehend and make his own and solve in his own way, is more likely to attack a problem of the same kind later on and thus go on with research after receiving his degree. It is in the interest of science to start a man so that he will keep going and will continue to produce after he has gotten away from the university."

The students and the professor form a team; they should work together as a group, exchanging ideas and each making contributions to the problem. Each should be given full recognition for his share in the work. This is important and is only fair. Nothing will more quickly kill the *esprit de corps* in a research group than the feeling that the individuals are merely cogs in a wheel, and the professor should be careful that no occasion arises to cause such feeling.

So much for the professor. What about the qualifications of the beginner in research? First of all, it must be remembered that not every senior is qualified for research, either by intellect or by aptitude. In addition to possessing at least a better than average scholastic standing, he must have demonstrated some degree of originality, must have a serious attitude toward his work, must be deeply interested in his chosen field, and must have demonstrated the ability to think clearly. Of course, he is not a finished product; if he were, he would not be a senior. But without reasonable qualifications he is doomed to failure. The professor can train the right type of potential research student but he can't put brains into his head.

This leads to the important question of the type of problem to be assigned. Too much care cannot be taken at this point. In selecting a problem for senior research great care should be taken to assign one for which the student is qualified. This is not always an easy task. Grades alone are not adequate to determine the capacities of students. One with a brilliant scholastic record may turn out to be a very ordinary research worker. An attempt at grouping the seniors should be made. Some students should do library research only; others are better suited for experimental research; perhaps a select few should be assigned a problem that requires both library and laboratory work. If the senior's time for research is very limited a library problem might be given, as this will not require time to design and build an apparatus, calibrate instruments, prepare and standardize solutions. Or, if he plans to go into high-school teaching, perhaps a library problem will be better adapted to his needs or better training for his next job. Even if he intends to continue with graduate studies, training in the use of a library will be most helpful to him; in fact, without it he is seriously handicapped. It is true that library research will probably not be original; but what of it? It will represent training in making a critical examination of facts and principles, and in organizing and evaluating findings. The student may, however, discover a new interpretation of a published experiment or he may turn up something of interest historically. And what is more fascinating than historical research? The library is a research tool, just as useful and just as necessary as the analytical balance. No one ignores instruction in laboratory method; why overlook the need of instruction in bibliographic method?

Some students work better with their hands than they do with their heads; and if they use their heads reasonably well, they may develop into good experimental research workers. Anyway, it might be wiser to start this type of senior on a laboratory problem that requires very little library work, since his research time is so limited. He should not, however, be used as a mere assistant or technician, being assigned various "pot-boiling" jobs which are not of sufficient importance for older and more experienced men, or perhaps required to prepare certain compounds for use in the researches of the professor. Such work is not research at all. Though it may be of value to the laboratory, it is valuable experience for the student only in the same sense that all laboratory courses are valuable.

A senior research problem should not be too difficult and it should not be too simple or trivial. It should not be too long or too involved and must be one that can be completed—or nearly, at least—in the time available. I have seen even young Ph.D. graduates killed as budding scientists because they were assigned to a problem clear beyond reach at their stage of development. The important thing (from the student's standpoint) is to develop the research spirit, and to gain experience and confidence in his own ability. To reach this goal he must really accomplish something worth while (at least

to him). It is important that the senior be in a position to feel he has really accomplished something of scientific value. He will meet with failures in later years, but by all means let him enjoy the thrill of success with his first research problem. Professor Reid (*3*) says:

"The student should avail himself to the fullest extent of the experience and knowledge of the professor without becoming too dependent. It is well for the student to start out along the path suggested by the professor and to rely more and more on his own judgment as his comprehension of the problem and his maturity increase."

Regardless of the type of research problem, the senior should be required to write it up with great care, as if for publication. While he should be encouraged to develop his own style of writing and expression, it would be well for him to study a number of published papers in standard journals; preferably, articles on work similar to his own. The writing of a thesis is in itself well worth while from the standpoint of the senior, whether he plans to go on with graduate studies or to take an industrial or teaching job.

A few years ago I was sitting in the office of the director of one of our largest industrial research laboratories, an organization that employs several hundred chemists and is continuously adding men to its staff. We were discussing young research workers and I asked the director if he could tell me in a few short sentences the weak points he found in the training of the men he employed. The first one I quote: "The inability to keep a neat record book and to write a good report." He went on to say that they did not permit new men to use the company's record books until they had been given training in the writing of reports. That the fault usually is not with the men was demonstrated by the rapidity with which most of them learned. "Indeed," said the research director,

"if a certain college or university should begin to train their chemistry students in how to keep neat and orderly record books and how to write technical reports, it would not be long until jobs for their graduates would far exceed the supply."

Certainly we all agree that it is one of the duties of an institution so to train its students, and it is a poor commentary on the professors when industrial laboratories have to teach college graduates the rudiments of recording data and writing intelligible reports. Senior research offers training in keeping an orderly record book and the senior thesis is valuable experience in report writing. Professor Emmet Reid (*4*) says,

"There are men who have excellent ideas and can do splendid work but will always hold subordinate positions because they lack the ability to present their results."

For over twenty years at the University of Virginia I have made a practice of focusing my attention on the upper ten per cent of my classes of undergraduate students, usually a group of four to eight. These men offer far more promise (as future chemists) than any other group that I might select. Of course, I will thus miss a few good men, but rather than dilute my efforts and scatter my energy over a larger number, or even the whole class, I feel that it is better to concentrate on a small, select group. I do not mean to imply that the average student or even the poorest student will not be given aid; but these men must come to me with their requests. At least in this way they demonstrate some interest, genuine or otherwise. The brighter students are met for extra discussions, either individually or as a group. Professor Kirk (*1*) is correct when he says,

"We have, in many cases, allowed the hordes of 'non-major' students to take our attention away from the best interests of the major student and the student of superior mental ability."

The senior doing research should be placed on a regular schedule. His research time should be definitely allocated, or at least the minimum number of hours per week expected of him should be scheduled, just as a lecture or laboratory period is scheduled. This is important for several reasons: (1) the student learns to systematize his work, (2) the professor will know when to find him at work in the laboratory or library when he wishes to drop in for an informal discussion, (3) it will insure him against neglecting his research. His research too often takes what is left over—in time, in thought, and in energy. The professor should not tolerate this state of affairs. Great improvement often results from assisting the student to organize his work—to budget his time.

There is no short cut to training in research. The only way to learn how to do research is to *do research*. You cannot learn how to analyze a limestone or a steel by reading the procedures, however carefully, although, of course, this should be done before beginning the analysis. Research is both an art and a science; it requires practice, the more the better.

Some might raise the question: If research is such a fine thing, why wait until the senior year? If the research method of approach is so excellent and fascinating, why deprive the junior, the sophomore, or the freshman? The answer is, I think, that these men should not be deprived. If we agree that the driving force in all research is curiosity, then surely the lower classmen will possess curiosity to some degree, for this is a natural instinct. These students should be given special attention. They should be encouraged to seek the answers to the questions they raise. Devise for them little problems and guide them in their work; from these lower classmen are to come the seniors and graduate students. How many questions can a three-year-old boy ask on a trip to town or to the country? Why doesn't this boy continue to ask questions when he grows up? Can it be that he has found all the answers; or has he run out of questions? Or, failing to get encouraging answers, does he simply stop in disgust?

By all means start seniors on research; but do not start all seniors. Some are definitely not qualified and the chances are they never will be; but the select few, the more promising ones, should be assigned suitable problems and a plan of attack should be mapped out for them. The objectives of senior research should be:

(1) to teach the undergraduates the real meaning of the word "research"; (2) to cultivate in them the scientific spirit; (3) to accomplish something valuable to science, however small it may be; (4) to make the institution known for its work in a particular field of chemistry; and (5) to act as a stimulus to all the class and laboratory work in the department—a stimulus to the professor as well as to the students.

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DISCUSSION OF THE PAPER

J. L. RIEBSOMER

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NOT only should senior research be limited to the better seniors, but also no senior should be allowed to take a research course involving any laboratory if he cannot spend at least eight clock hours per week at this work. If the work is to be confined to reading only, then a shorter weekly period may be satisfactory.

If we are agreed that only the better seniors should be allowed to take this research course and if scholastic standing is not to be the sole basis of selection then how is it possible to determine wisely and justly who shall be chosen? Should only those seniors who plan to go to graduate school be encouraged? Or is it equally or more important for the man who plans to go into a job directly from his undergraduate work? Who is to judge the merits of any given case? Certainly, it is not wise to insist that every man must have a certain grade record before being allowed to take senior research.

The problem of selecting the proper seniors is not so difficult in the smaller schools such as ours because one or at most two men do all the advising of chemistry majors and are usually quite intimately acquainted with the student by the time he is a senior. Furthermore, it is possible to eliminate almost all of the misfits before their senior year either by persuasion or by failing grades. Accordingly, it is my feeling that in the smaller schools nearly every senior chemistry major who plans to make a living from his chemistry should take senior research.

In the larger schools this problem may be more difficult. But even in a large department a few people of professorial rank should act as a committee to keep in touch with the records and work of all majors so that answers to questions of this type can be had.

The problem assigned must be one which the professor has studied carefully and preferably one with which he is quite familiar, not only with the literature but with the actual laboratory practice. When the student has trouble (which is most of the time) the professor should be adequately prepared to give a reasonable hint which will make the work successful; he must be alert to the detailed conditions of the general reactions involved so he can quickly spot errors.

In assigning problems it is highly important to make it clear to the student just what significance his work has. Point out to him the broader program of which his problem may be a small part. The broad program must have some real sound significance, so that the student will feel that he is in a position to make an important contribution by his efforts.

There is some question in my mind as to the value of library research for most seniors. I can agree that there might be some cases in which it would be appropriate. On the whole, however, I believe it should be avoided. My reason is that any research is not and cannot be pure library work. Everyone agrees that no new facts are ever established in the library, however important the library may be for research. Therefore, the student should be led to feel that library work is not research in itself but only a part of the process. The ideal situation is to assign to the student some topic for reading at the first of the year, instruct him in the use of the abstracts, etc., and let him write a paper on this topic, to be turned in by the middle of the year. The topic chosen should be related as closely as possible to his research problem. This procedure serves the double purpose of library training and a broader acquaintanceship with the research problem. If it is not possible to assign reading closely related to the research and if the student knows where he is going to graduate school we sometimes assign topics with which he is likely to deal in graduate work. If, for example, he plans to go to Wisconsin, we might assign a topic on "Catalytic Hydrogenation." Or if he plans to go to Purdue we might assign a topic on "Chlorination and Nitration of Hydrocarbons."

I am in complete agreement that seniors should not be used primarily as exploring agents to find new problems to assign to graduate students. We must remember that research is a brand new toy to a senior and he must be shown how it works before we can expect him to make much progress. At some time or other the professor should do all general exploratory work himself—and that goes also for professors in the graduate schools. This does not mean that the professor does all the student's work or thinking for him. It simply means that he gives the student a send-off and that at all times he knows as much or more about the essential facts of the study than does the student. After the student has a proper incubation period the professor will usually find himself in a position to learn from the student—an opportunity which he should never miss, because it is not only educational but also it gives the student the proper feeling of importance.

But we must not overlook the fact that chemical research requires assistants and "potboilers." I believe that seniors should have to do a considerable amount of the grinding routine and "potboiling" type of work, because, after all, this is the real source of new facts, new compounds, and new theories. Since this is such an important part of research the student should have a real taste of it; otherwise he may get the wrong concept.

It is highly important that the professor be on the alert to prevent undue discouragement on the part of the student. An encouraging word, a smile properly placed, or a little pep talk occasionally may have its place in maintaining the student's morale until a little success opens the problem. Usually a little success ends all need for further help of this kind. Above all, the professor must keep reminding the student that he (the professor) has an interest in the outcome of the research.

As a teaching method, senior and staff research in an arts college does more to bolster the morale, achievements, interests, standards, and reputation of the department than any other single thing to which we can point.

Courses in Advanced Inorganic Chemistry[1]

P. W. SELWOOD[2] *Northwestern University, Evanston, Illinois*

THE accrediting committee of the American Chemical Society does not, in its wisdom, specifically require training in inorganic chemistry. In view of this action it may first be necessary to establish the reality of such a thing as inorganic chemistry, and then to show that it is indispensable in the training of any chemist.

Inorganic chemistry can be discussed only in terms of what the student has learned in his first two years of college, and what he is likely to learn if he proceeds to graduate study. Unless a school is one whose only function is the training of chemical technicians, there can be no excuse for regarding first-year general chemistry and inorganic chemistry as the same thing. Inorganic chemistry is a difficult subject which may be treated adequately, even from a purely descriptive standpoint, only before relatively mature students.

In order to lend a little weight of authority to these remarks, the writer communicated with most of the leading chemical research directors in the country, asking three questions:

1. Is there a definite place for men trained in inorganic chemistry in your organization?
2. How does the demand for inorganic chemists compare with that for other chemists?
3. How should the inorganic chemist be trained?

The interest in these questions was astonishing; one man was kind enough to send three letters, a pamphlet, and a book. Both from the academic and from the industrial points of view, the answers to these questions, in a nutshell, are as follows:

There is a definite demand for inorganic chemists, although the demand in different organizations may run from 5 to 95 per cent of all chemists employed. The overall demand is roughly twenty per cent of the whole, that is, about the same as for physical chemists and about half of that for organic chemists; and, with regard to the training, the student should have a broad fundamental background and let his specialization take care of itself.

In order to illustrate the general interest in this problem, the following is quoted from part of one of the many letters received.

"I was glad to receive your letter regarding the training and demand for inorganic chemists. I believe that, during the past decade, the rapid rise of importance of organic chemicals has to a noticeable degree overshadowed the importance of the inorganic field. This has, unfortunately, been taken by many as an indication of a decreasing importance of the inorganic field. This of course is not so. The inorganic field is likewise increasing in importance with the passage of time, but its rate of progress has obviously not been as great as the organic. The fundamental importance of the inorganic field remains as great as ever.

"I shall try to answer your questions in the order that you asked them.

"1. There is very definitely a place in industrial chemistry for men trained in the inorganic field. Such men are needed in the production and management end of industry and in certain phases of research work.

"2. My personal experience is that the demand for inorganic and physical chemists is about on a par. The demand for organic is at present several times greater and for analytical, somewhat less, than that for inorganic and physical.

"3. The matter of training of the inorganic chemist is a difficult one to answer. Personally, I classify inorganic and physical chemists so closely together that it is frequently difficult to distinguish between them.

"In post-graduate work for inorganic chemists, I think either of two courses can be followed with equal satisfaction. First, if a man shows a strong interest in a highly specialized field, he should obviously be permitted to specialize in this field, even though his training becomes somewhat narrower. If the man has no such strong interests then I believe he should be given as broad a training as possible in both physical and inorganic. Obviously there must be some degree of specialization even in the broad training. Emphasis of a minor nature can be placed upon that particular phase in which he or his instructors believe him best suited, such as fundamental research of the academic type, electrochemistry, industrial chemistry, or chemical economics.

"I am fully aware of the importance of proper training and the direction of interests of graduate students. I have been for some time convinced, however, that if the man has the proper ability and initiative his own breadth of interests will be sufficiently great so that he will be a usable individual in almost any field of industrial inorganic chemical activity, whether or not that field is within his own area of specialization. This view, of course, boils down to the fact that a good man will be able to adapt his education to the needs of the situation."

The demand for inorganic chemists apparently exceeds the supply, and it sometimes happens that inorganic problems have to be placed in charge of men not particularly well fitted, by training, to undertake them. One research director wrote,

"I was particularly interested in your letter because of the difficulty we have had in finding men with sufficient inorganic training."

This situation is by no means generally recognized. The chairman of one large chemistry department believes in a balanced department and automatically places students interested in inorganic doctorate work near the top of his assistant list. Another, however, actually discourages people from working in inorganic chemistry because he thinks it is impossible to place men so trained.

Inorganic chemists are urgently needed, not only in the field of inorganic synthesis, but in the allied fields of ceramics, geochemistry, and synthetic metallurgy, where the application of scientific chemical principles has barely begun. The pages of an inorganic chemistry such as Mellor's "Treatise" abound in references to inorganic compounds which have been discovered but

[1] Presented as part of a Symposium on the Teaching of Advanced Undergraduate Courses in Chemistry, sponsored by the Division of Chemical Education at the 101st meeting of the A. C. S., St. Louis, Missouri, April 8, 1941.

[2] The writer is indebted to Mr. David Richman for assistance in the preparation of this paper.

for which there is no known use. There can be no doubt that much remains to be done with this subject and that it must be considered as a relatively new field, rather than one that is all worked out.

In view of the fact that the field of inorganic chemistry covers practically all of the known ninety-odd elements other than carbon, it is difficult to be specific regarding the exact nature of the specialized training of the inorganic chemist. But most research directors believe that chemists should be trained in fundamentals and that highly specialized training can be possibly a great waste of time. Specialized knowledge can far better be acquired after entering industrial life, or after developing a research interest in academic life. It is general experience that a man having a broad picture of the chemical fields, inorganic, organic, and physical, develops faster than one too highly specialized. Men are wanted who can call themselves physico-inorganic or inorganic-physical chemists. Many organizations place physical and inorganic training in the same category.

Next to a broad training in the fundamentals, the characteristic most desired is research ability. That implies ability to organize a problem, to plan the day's work, to show resourcefulness in the face of difficulty, and stubbornness in the face of defeat, and to maintain the most rigid standards of personal intellectual integrity. By its very nature research training implies a high degree of specialization. Although research experience is essential to the training of any chemist, it must be amplified or, better, based on a broad introduction to research tools and technics.

With these considerations in mind, it is suggested that the curriculum in inorganic chemistry should consist of three courses:

1. A course in descriptive inorganic chemistry for sophomores or juniors.
2. A course in theoretical inorganic chemistry for seniors or first-year graduate students.
3. An advanced laboratory course serving as an introduction to inorganic research.

The first, descriptive course should be required of all chemistry majors. The descriptive and the theoretical courses should be required of all graduate students in chemistry, and all three courses, together with appropriate research, for the doctorate in inorganic chemistry.

The descriptive inorganic course for sophomores or juniors should be exactly what the name implies. It should be a thorough presentation and drill on the properties and reactions of the elements, not omitting the less familiar elements. The course should not be cluttered up with physical chemical principles or hypotheses regarding chemical behavior. This course should be given by a man whose major interest is in descriptive, preferably synthetic, inorganic chemistry. The theoretical aspects of inorganic chemistry are properly taught nearer the graduate level after the student has absorbed the elements of physical chemistry.

Among the several texts available for this course the writer prefers the new edition of Latimer and Hildebrand's "Reference Book of Inorganic Chemistry" (*1*). As a matter of fact, the course need not go much beyond the inorganic matter in a text such as Schlesinger's "General Chemistry" (*2*). This is material to which the freshmen are often exposed, but which they seldom assimilate. General understanding that such material was to be covered thoroughly in a sophomore or junior course would relieve the pressure on the freshman course to include much material irrelevant to elementary general chemistry. And general adoption and requirement of such a course might diminish the number of graduate students who come to us, even from leading universities, without knowing that the hydrogen *ion* is not a very powerful reducing agent. Laboratory work should be a part of the course. A satisfactory selection of experiments may be found in Henderson and Fernelius's "Inorganic Preparations" (*3*).

At Northwestern University a one-semester course of this type is required of chemistry majors and is often elected by first-year graduate students. Some departmental opposition to the addition of this course to the chemistry major requirement rapidly disappeared when it was pointed out that first-year general chemistry no longer includes the thorough study of inorganic chemistry that was common twenty or thirty years ago.

Experience with this course has been thoroughly satisfactory. It has grown every year, increasing in popularity especially with geology majors and with first-year graduate students who feel their preparation in descriptive inorganic chemistry to be inadequate.

The course in theoretical inorganic chemistry, designed for seniors and first-year graduate students, is elected almost exclusively by graduate students at Northwestern. This course bears little resemblance to most courses bearing the name of "Advanced Inorganic Chemistry." But, as Professor Forbes has recently pointed out in the JOURNAL OF CHEMICAL EDUCATION (*4*),

> "Most students prefer the study of organic and physical chemistry to that of inorganic because the facts of inorganic chemistry appear unrelated. This impression should not be allowed to persist. The teaching of inorganic chemistry will gain in vitality and coherence if frequent glimpses are given of the general principles which unify the entire subject."

Unfortunately, few students are able to comprehend these unifying general principles until they have had at least one year of physical chemistry, as well as adequate training in descriptive inorganic chemistry. A year of physical and at least one semester of inorganic chemistry, or qualitative analysis, are therefore made prerequisite to the course in theoretical inorganic chemistry. The semester of descriptive inorganic or qualitative is, of course, in addition to the first-year general chemistry course. It is found that about half the graduate students at Northwestern have these prerequisites when they come to us.

When the writer began to give this course five years ago there was no text which came near to covering the subject matter in a satisfactory fashion. But during the past two or three years several books have appeared

which, in combination, present a fairly satisfactory picture of the course. These are Emeléus and Anderson's "Modern Aspects of Inorganic Chemistry" (*5*), Pauling's "Nature of the Chemical Bond" (*6*), and O. K. Rice's "Electronic Structure and Chemical Binding" (*7*).

The subject matter includes a very brief introduction to atomic structure, an introduction to molecular structure, and a fairly thorough discussion of valence forces and molecular aggregation as found in inorganic compounds. This includes coördination compounds, intermetallics, and interstitial compounds. This is followed by a survey of methods used in the structural analysis of inorganic compounds, that is, by a brief discussion of thermal analysis, X-ray diffraction, molecular spectra, dipole moments, magnetic susceptibilities, and electron diffraction. The course continues with exercises in the use of Latimer's "Oxidation Potentials" (*8*), and concludes with a survey of modern isotope chemistry. Sometimes it has proved possible to include a brief discussion of nuclear chemistry.

The course is therefore partly review, partly survey, and partly fairly intensive study of modern developments. For some of the students much of the material is not new, for others it is practically all unfamiliar. The main objective of the course is to unify much material of which the student may have heard but which he does not thoroughly understand. The course also serves as preparation for the preliminary examination for the doctorate, and it marks the limit in inorganic chemistry for which non-inorganic majors are held.

This course does not include laboratory work, although students sometimes take the laboratory work of the descriptive course at the same time. The course has proved to be uniformly popular with the faculty, who support its inclusion in the curriculum. Perhaps it has proved a little less popular with the students because of a partly undeserved reputation for difficulty.

The last of the three courses in advanced inorganic chemistry is the laboratory course which might be called "Introduction to Inorganic Research." So far, because of lack of facilities and space it has not been possible to introduce this course at Northwestern, but it is hoped that this can be done soon. The necessity for such a course arises from the fact that research, no matter how indispensable it may be, tends toward specialization. Research must rest upon a boader base than can be achieved in the average research problem. The training of inorganic chemists can scarcely be made too broad because the problems arising from the manufacture and servicing of hundreds of inorganic chemicals are extremely varied. The course should, therefore, be designed to give the student a wealth of experience in different technics applicable to the field of inorganic chemistry.

At this stage one doubts the usefulness of a formal laboratory manual. The student should rather be encouraged to draw from the current literature and from such works as "Inorganic Syntheses" (*9*). Direction by the instructor should be restricted to seeing that the student acquires a sufficiently varied experience in the several preparations and problems he undertakes. Probably the ideal way would be for the instructor, on the student's first appearance in the course, to ask him what he would like to do. If the student replies that he does not know, then he should be told to come back six months later after he has made up his mind what he wants to do. Such Spartan measures would probably result in the course having few students, but they would all be good ones.

Chief emphasis should be placed on synthesis, or process working, based on useful application of the element or elements under study Many active branches of inorganic chemistry, for instance metallurgical chemistry, do not consist of analysis, but from an investigational point of view are composed of synthetic procedures and activities. Attention should also be given to the importance of traces of impurities on the course and speed of reactions, and on the properties of the products. The use of ultra-sensitive tests should be encouraged, and the quality and yield of products should be carefully traced. Investigative ability is more often acquired than inherited; no effort should be spared to see that students get the maximum benefit from their university experience. Quantitative methods of thinking, the creative attitude, alertness, intelligent planning of the day's work, the ability to write or deliver concise interesting reports, unfailing honesty; all these things can be promoted by conscious effort on the part of the instructor. Of course, personal qualifications are more important than any training. But given two men of equivalent personal qualifications, there can be a world of difference in the one exposed to careful training under a great scientist and teacher.

The establishment of such an "Introduction to Inorganic Research" may prove difficult. In the writer's experience the lack of space and equipment has proved until now an insurmountable obstacle. Even with the prospect of greatly increased space some opposition by the faculty may be anticipated. The opposition may take the stand that: "We have at present only two very active divisions in our department, organic and physical. Why allocate considerable space and a large sum of money for a course for which there is obviously no need?"

The writer hopes that his remarks have shown the fallacy of such arguments, and have pointed to the renaissance of inorganic chemistry which is most certainly on the way.

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DISCUSSION OF THE PAPER

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THE problem of introducing a review course in general chemistry is one which each college must solve individually. There are many conditions which should be considered before such a step is contemplated.

First, is such a course necessary? This will depend upon the content of the first-year general chemistry course and the time devoted to it. If it is quite comprehensive and sufficient time has been allowed, and if a course in physical chemistry is also offered, a review course may not be needed. However, if the first-year course is a "short course" which is combined with qualitative analysis, it is quite possible that a review course may be needed before the student goes on with the advanced work.

Second, is there time and space for such a course in the chemistry curriculum? Here again it becomes a problem peculiar to each college. Where the number of courses offered in the chemistry department is limited, and where the aim of the department is to prepare the student for his graduate work by offering the fundamental courses—general, analytical, organic, and physical, with a full background of cultural courses—it is possible that a review course might be offered in the junior or senior year. However, there are some colleges which plan to turn out full-fledged chemists, ready for industry, in four years. In such institutions the student's time is fairly well taken up with more specialized work such as advanced analytical chemistry, electrochemistry, biochemistry, colloids, analytical organic, microchemistry, fuel analysis, food chemistry, etc., and there is no time for a review course. It is my personal opinion that such colleges should extend the time to a five-year period, include more of the cultural course which is omitted under the present circumstances, and thus turn out a more social individual, instead of a narrow-minded specialist, who may not be able to write a satisfactory report or use the library to best advantage. Perhaps a review course could be introduced in the senior year.

Third, what should be the content of such a review course and how should it be given? It may be a lecture and recitation course in which the fundamental principles and newer concepts of chemistry are considered. The student may be required to read the journals and special reference books, thus acquiring facility in the use of the library, to submit reports on some of the latest developments in the science. Or it may be a laboratory course devoted to the development of special skill in assembling and manipulating apparatus, which will prepare the student for research and industry. If it is the aim of the college to prepare the graduate for some specialized field in industry, the course may be modified accordingly.

Fourth, will there be time for such a course in view of the demand of the administration to speed up engineering courses for the defense program? It does not seem probable.

The problem before the colleges is a consideration of the end for which they are preparing the student—industrial work, or graduate study and specialization. Does the entering freshman know what he plans to do for his life work? Is it fair to make him choose a career at that point? In the majority of cases it would be far better to offer the student a four-year integrated course, during which time he can make up his mind regarding his future. Specialization in the graduate school will take care of the rest, and hence the review course might be offered in the senior year or first year of graduate work.

Editor's Outlook

(*Continued from page 401.*)

IT SCARCELY seems necessary to argue the importance of mathematics as a working tool for the trained chemist. Certainly no reputable institution for the education of chemists fails to assure its graduates of an adequate mathematical background for modern physical chemistry, which means a thorough knowledge of calculus, at least. To be sure, there are many of us who, from deficiencies in our own training or from pure intellectual inertia, turn the pages hastily when a few differential equations loom up on the horizon, but we do it furtively with full realization that we are shirking our duty to ourselves.

This is as much of an apology as we feel it necessary to make for presenting in this issue the paper by Professor George Glockler, which indeed we feel unusually fortunate in having obtained. The subject with which it deals is one which cannot be dodged indefinitely; sooner or later it crops up. The author's effort to present it understandably, but sufficiently rigorously, at the level of elementary physical chemistry brings it into the field which we have agreed the JOURNAL should try to serve. We have long believed that many "new" topics, ordinarily reserved for graduate courses, can be made understandable and useful at a more elementary level. Remember what happened to isotopes and nuclear reactions, which are now part of our elementary textbooks. Perhaps wave mechanics will not wash down quite so far, but who knows?

PROFESSOR Ernest A. Wildman, formerly of Earlham College, is an old member of the Division of Chemical Education and has many friends and colleagues who will be interested in what he is now doing. They will find a picture of him and an account of his latest activities in *The Saturday Evening Post*, August 16, page 54.

Teaching of Introduction to Wave Mechanics[1]

GEORGE GLOCKLER

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IN ORDER to understand the modern theories of chemical valence and chemical binding it is essential that the student obtain in his course in physical chemistry and physics an adequate presentation of the science of wave mechanics. It is hoped to show that this aim can be accomplished in a manner which permits the possibility of making a connection with the earlier classical thought with which the student has dealt in his beginning courses in chemistry. Furthermore it is of great importance that the fundamental notion of quantization be described in a proper way so that the student can learn to make the transition from former ideas which did not involve these modern concepts of radiation and atomic structure. To this end the following outline of a series of topics pertinent to the problem was used for a number of years in a course of physical chemistry.

1. Bohr Theory.—Introduction to Bohr theory; the quantum condition $\oint pdq = nh$; the hydrogen atom; the spectra of hydrogen and ionized helium; the hydrogen atom, involving the motion of the nucleus; deuterium, its discovery and spectroscopy; the Rydberg constant; the helium atom; two-electron systems; the electron affinity of hydrogen; estimated electron affinities of the light elements; the hydrogen mol ion; the hydrogen molecule; the harmonic oscillator; the rigid rotator; the hydrogen halides and their rotation spectra; rotation-vibration bands; potential energy curves of diatomic molecules.

2. The Vibrating String.—The equation of motion; Bernoulli's method of solution of the differential equation; boundary conditions; period of motion; frequency of motion; integral relation between frequency of fundamental and overtones for a macroscopic system.

3. Critical Speeds of Shafts.—Stationary shaft; shaft bent by its own weight; weightless rotating shaft with concentrated load at center; rotating shaft of uniform weight per unit length; shaft with initial eccentricity; critical speeds for shafts depending on a system of integers.

4. The Classical Wave Theory and the Modern Quantum Theory of Radiation.—Rectilinear propagation; emission and absorption; temperature radiation; polarization; interference; diffraction; photoelectric effect; Compton effect; Tyndall effect; Raman effect; energy and momentum of radiation; radiation pressure; Kerr and Faraday effect; particles and waves; Davisson-Germer experiment; electron diffraction; de Broglie's concepts of radiation and particles; radiation has wave and particle aspects; particles have wave aspect.

5. Introduction to Wave Equation.—Derivation of Schroedinger equation from general wave equation of physics pertaining to periodic phenomena; de Broglie wave length; wave equation not including the time for various systems; systems of differential equations involving proper value problems and proper functions; the linear harmonic oscillator on wave mechanics; Hermitian polynomials and graphic illustration; the hydrogen atom; the helium atom; electron spin; exchange degeneracy; perturbation theory; the hydrogen mol ion; the hydrogen molecule; nuclear spin.

[1] Presented as part of a Symposium on the Teaching of Advanced Undergraduate Courses in Chemistry, sponsored by the Division of Chemical Education at the 101st meeting of the A. C. S., St. Louis, Missouri, April 8, 1941.

THE HYDROGEN ATOM ON BOHR THEORY

The presentation of atomic structure problems on the basis of Bohr's quantum condition can be carried out quite simply and consistently on the following plan, illustrated by the case of the hydrogen atom:

1. After a definite model of the atom has been decided upon, as in this case a stationary nucleus with one revolving electron at a distance r, the total energy of the system W can be written

$$W = K.E. + P.E. = {}^1/_2 mv^2 - \frac{e^2Z}{r} \qquad (1)$$

where

$K.E.$ = kinetic energy of the system
$P.E.$ = potential energy of the system
m = mass of the electron
v = velocity of the electron in its orbit
e = charge on the electron
Z = charge on the nucleus
r = radius of the circular orbit

Inserting the atomic number of the nucleus makes the equation applicable to all one-electron systems instead of to hydrogen only.

2. The forces acting on the electron are the electrical coulomb force and the mechanical or centrifugal force due to its motion. They must balance

$$\frac{e^2Z}{r^2} = \frac{mv^2}{r} \qquad (2)$$

and substitution in (1) gives

$$W = -\frac{1}{2}\frac{e^2Z}{r} \qquad (3)$$

3. The famous quantum condition of Bohr $\oint pdq = nh$; $n = 1, 2, 3 \ldots$ applied to the periodic motion of the electron yields

$$\int_0^{2\pi} mvrd\theta = nh = 2\pi mvr \qquad (4)$$

where

p = angular momentum = mvr
$dq = d\theta$ = coördinate
n = an integer
h = Planck's constant

Equations (2) and (4) yield

$$r = \frac{n^2h^2}{4\pi^2mZe^2} \qquad (5)$$

showing that not all values of the radius are possible. Only a given set exists depending on the square of the integer n. Substitution of (5) in (3) shows that

$$W = \frac{-2\pi^2me^4Z^2}{n^2h^2} = 13.52 \text{ e.v.} \qquad (6)$$

The check of this calculation with experiment is of

course one of the great triumphs of Bohr theory. The three steps just outlined for the hydrogen atom can be carried through rather consistently for the other atomic and molecular systems mentioned.

TWO-ELECTRON SYSTEMS

When, however, two-electron systems such as helium, lithium ion, etc., are studied, it is found that Bohr theory does not yield correct results when compared with experiment. However the first ionization potentials are not altogether out of line as Table 1 shows:

TABLE 1

FIRST IONIZATION POTENTIALS

Z	*System*	*Bohr*	*Experiment*
1	H^-	1.69 e.v.	0.70 e.v.*
2	He	28.69 e.v.	24.50 e.v.
3	Li^+	82.70 e.v.	75.28 e.v.
4	Be^{++}	163.70 e.v.	153.15 e.v.

*Wave mechanical calculation.

One gains the impression that the fundamental idea of Bohr (dynamical atom like a solar system) is not entirely erroneous but needs some modification. Hydrogen mol ion and hydrogen molecule similarly are not properly presented by a Bohr calculation.

THE VIBRATING STRING

At this juncture of the development a discussion of the vibrating string offers several advantages. First of all, it gives an opportunity to derive a simple differential equation. The Bernoulli method used for its solution is most valuable, because the Schroedinger wave equations, later to be encountered, can be solved by the same method. Some of the details may be mentioned. The equation of motion for the vibrating string is

$$\frac{\partial^2 y}{\partial t^2} = a^2 \frac{\partial^2 y}{\partial x^2} \tag{7}$$

where

y = small displacement of element of string of length dl at x
x = location of element dl from origin where one end of string is fastened at $x = 0$
t = time
a^2 = constant $= P/(q\sigma)$
P = tension in string
q = cross section of string
σ = density of the material of the string

The method of separation of variables is then applied in trying to find a solution for equation (7). It is assumed that a solution can be found

$$y = X(x) \cdot T(t) \tag{8}$$

such that $X(x)$ depends on x only and $T(t)$ depends on t only. Differentiating partially twice in respect to x and t and substituting in (7) yields

$$(a^2T)^{-1} \cdot \frac{\partial^2 T}{\partial t^2} = X^{-1} \cdot \frac{\partial^2 X}{\partial x^2} \tag{9}$$

The left side of equation (9) is a function of t only and the right side is a function of x only. In order that equation (9) be valid both sides must be equal to a constant:

$$(a^2T)^{-1} \cdot \frac{\partial^2 T}{\partial t^2} = X^{-1} \cdot \frac{\partial^2 X}{\partial x^2} = -c^2 \tag{10}$$

where c^2 is the separation constant and two simpler differential equations result

$$\frac{\partial^2 T}{\partial t^2} + a^2 c^2 T = 0 \tag{11}$$

and

$$\frac{\partial^2 X}{\partial x^2} + c^2 X = 0 \tag{12}$$

Rather than to write down the well-known solutions it is better to solve these equations by assuming a power series solution, because this method is useful for equations later to be found in other problems on wave mechanics. It is assumed that a power series solution can be obtained

$$T = \Sigma a_k t^k \tag{13}$$

where a_k = constant and $k = 1, 2, 3 \ldots$. Differentiating twice, placing the derivative into equation (11), yields an identity whose coefficients are equal to zero, leading to a recursion formula

$$a_{k+2} = \frac{-a^2c^2}{(k+2)(k+1)} \cdot a_k \tag{14}$$

Evaluating the constants of equation (14) in terms of two of them, a_0 and a_1, and placing their values into (13), brings

$$T = a_0\left[1 - \frac{(act)^2}{2!} + \frac{(act)^4}{4!} - \frac{(act)^6}{6!} + \ldots\right] + \frac{a_1}{ac}\left[act - \frac{(act)^3}{3!} + \frac{(act)^5}{5!} - \ldots\right] \tag{15}$$

or

$$T = a_0 \cos(act) + \frac{a_1}{ac} \sin(act) \tag{16}$$

which is the general solution of (11). Equation (12) yields on similar treatment

$$X = b_0 \cos(cx) + \frac{b_1}{c} \sin(cx) \tag{17}$$

and the solution of equation (8) is

$$y = X \cdot T = \left\{b_0 \cos(cx) + \frac{b_1}{c} \sin(cx)\right\} \cdot \left\{a_0 \cos(act) + \frac{a_1}{ac} \sin(act)\right\} \tag{18}$$

Applying the boundary conditions $y = 0$ when $x = 0$ and $y = 0$ when $x = l$ (l = length of string) shows that the separation constant $c = n\pi/l$, where $n = 1, 2, 3 \ldots$ $b_0 = 0$ and (18) can now be written

$$y = \sin(n\pi/l)\{A \cos(act) + B \sin(act)\} \tag{19}$$

where $A = (b_1a_0)/c$ and $B = (b_1a_1)/(ac^2)$. At constant x the displacement becomes

$$y = C\{A \cos(act) + B \sin(act)\} \tag{20}$$

or

$$y = C_1 \cos(act) + C_2 \sin(act) \tag{21}$$

where C, C_1, and C_2 are constants. By trigonometric

transformation, the last equation can also be written in terms of the maximum displacement (y_{max}) at x = constant:

$$y = y_{max} \cdot \sin(act + \epsilon) \tag{22}$$

or

$$y = y_{max}\{\sin\epsilon \cdot \cos(act) + \cos\epsilon \cdot \sin(act)\} \tag{23}$$

Comparing (21) and (23) shows that

$$C_1 = y_{max} \cdot \sin\epsilon \quad \text{and} \quad C_2 = y_{max} \cdot \cos\epsilon \tag{24}$$

Of more interest is the time t_{max} when the displacement itself becomes y_{max}. For then

$$y_{max} = y_{max} \cdot \sin(act_{max} + \epsilon) \tag{25}$$

or

$$\sin(act_{max} + \epsilon) = 1 \tag{26}$$

or

$$t_{max} = \frac{\pi}{2ac} - \frac{\epsilon}{ac} + \frac{2\pi n}{ac} \tag{27}$$

Two successive values of t_{max} define the period of the motion τ

$$\tau = t_{max}(n+1) - t_{max}(n) = \frac{2\pi}{ac} \tag{28}$$

and the frequency of motion ν is

$$\nu = \frac{1}{\tau} = \frac{ac}{2\pi} = \frac{an}{2l};\ n = 1, 2, 3 \ldots \tag{29}$$

Now at long last we see that the possible frequencies of motion of the vibratory string are given in terms of a set of integers

$$\nu_1 = \frac{a}{2l};\ \nu_2 = 2\left(\frac{a}{2l}\right) = 2\nu_1;\ \nu_3 = 3\left(\frac{a}{2l}\right) = 3\nu_1; \ldots \tag{30}$$

The string will vibrate with its fundamental or its overtones. No other frequencies are possible! We find a macroscopic system (the vibrating string) as a physical entity capable of vibrating states which are governed by a set of integers 1, 2, 3.... There is no feeling of alarm or strangeness because we can observe the string readily and directly enough and verify the result of our calculations. If we now analyze the problem and consider the way in which these integers were introduced into the discussion we find that the application of certain boundary conditions produced this special feature.

The same treatment can be accorded atomic systems in the sense that a certain differential equation is written for the case at hand. A solution is attempted by separation of variables, simpler differential equations result, recursion formulas appear, and whole-number relations come to the fore, to our astonishment! But should we be surprised? Not necessarily, if we remember the present problem of the vibrating string and the solution just presented.

Another mechanical problem analogous to the string is the rotating shaft. It is much more complicated, however, and the details would not be of interest in the present connection. Except, of course, the result, which shows that there are certain critical speeds for such shafts at which they begin to bend in wave-like patterns. Again this action depends on integers. These critical speeds are given by

$$\omega = (2n-1)^2 \left\{\frac{\pi 4EI}{Wl^4}\right\}^{1/2};\ n = 1, 2, 3 \ldots \tag{31}$$

where

E = modulus of elasticity
I = moment of inertia
W = unit load
l = length of shaft

We see once more a large scale physical system dependent on a set of integers 1, 2, 3....

DUAL THEORY OF RADIATION

With this background established, the next step consists in a very brief review of the nature of radiation, namely, stressing the wave and quantum theories of light. The various phenomena pertaining to the interaction of radiation and matter are studied in reference to our ability to explain them by either wave or quantum concept. Such phenomena as polarization, diffraction and interference of light, the photoelectric effect, the Compton effect, and the Raman effect can only, or perhaps most simply be discussed on a quantum picture of radiation. The dual nature of light as a wave phenomenon on the one hand and as a case for quantum consideration on the other hand is stressed to the greatest extent. For here lies the crux of the matter under discussion. If the listener gets the spirit of the development he will be aroused to the extreme difficulty of having to get along with a dual theory on radiation!

DE BROGLIE'S IDEA

Then the remarkable contribution of de Broglie comes to the rescue as a climax. The audacity of applying the dual concept to ordinary particles such as electrons appears as it really is: an outstanding contribution to human thought. Particles such as electrons have wave-like properties and under certain circumstances behave like waves! Hence the dualism, wave-particle and particle-wave, is complete. The idea does satisfy our inherent and innermost desire toward unity in physical thought. Or are we merely paying tribute to our desire for symmetry and simplicity? The natural sequence in discussion leads of course to the experiments on electron diffraction by Davisson-Germer and G. P. Thomson.

SCHROEDINGER'S WAVE EQUATION

The fundamental idea of de Broglie was that particles such as electrons have wave-like properties, shown clearly by the fact that they can be diffracted by the appropriate grating-like arrangement of atoms on the surface of a solid. It now appears simple enough to believe, with Schroedinger, that some sort of wave equation should describe the behavior of these particles.

Many phenomena are known to act in a manner such that they can be described by a wave equation.

For example, the electrical and magnetic forces of electromagnetic fields, the elastic properties of solids, pressure in fluids, and many other periodic occurrences can be dealt with by a general wave equation. The differential equation of the vibrating string was one example of this equation. It may be written

$$\nabla^2\Phi - \frac{1}{c^2}\frac{\partial^2\Phi}{\partial t^2} = 0 \tag{32}$$

where

∇^2 = Laplacian operator $= \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$
Φ = E, H, P, y (electric field, magnetic field, scalar pressure, displacement)
c = velocity of wave phenomena
t = time

The quantity Φ depends on the place (coördinates) and the time. If the phenomenon is a periodic one we suppose that

$$\Phi(x, y, z, t) = \psi(x, y, z) \cdot T(t) \tag{33}$$

and

$$T(t) = e^{-2\pi i\nu t} \tag{34}$$

where

$\psi(x, y, z)$ = function only of the coördinates
$T(t)$ = function only of the time
$i = \sqrt{-1}$
ν = frequency of the periodic phenomenon
t = time

Equation (33) can be separated into a "space-part" and a "time-part."

The space-part can be written

$$\nabla^2\psi(x, y, z) + \frac{4\pi^2\nu^2}{c^2}\psi(x, y, z) = 0 \tag{35}$$

or briefly

$$\nabla^2\psi + \frac{4\pi^2\nu^2}{c^2}\psi = 0 \tag{36}$$

this is the differential equation which $\psi(x, y, z)$ must obey. In terms of the wave length of the periodic phenomenon, since

$$\lambda \cdot \nu = c$$

where

λ = wave length
ν = frequency
c = velocity

equation (36) becomes

$$\nabla^2\psi + \frac{4\pi^2}{\lambda^2}\psi = 0 \tag{37}$$

This equation must now be adapted to a particle. In order to accomplish this purpose we consider first the famous Einstein relation, which gives the connection between the wave and quantum theories of radiation

$$E = mc^2 = h\nu \tag{38}$$

where

E = energy of a quantum of radiation
m = mass of the quantum
c = velocity of light
h = Planck's constant
ν = frequency of the radiation

The momentum of the quantum is

$$mc = \frac{h\nu}{c} = \frac{h}{\lambda} \tag{39}$$

The wave length of the quantum is

$$\lambda = \frac{h}{mc} = \frac{h}{\text{momentum}} \tag{40}$$

If then, as de Broglie supposes, particles have wave-like properties it may be that this feature can be described by a wave length pertaining to this particle

$$\lambda_{pt} = \frac{h}{mv} \tag{41}$$

where

λ_{pt} = wave length of the particle
h = Planck's constant
m = mass of particle
v = velocity of particle
mv = momentum of particle

Now the wave equation describing the particle can be written

$$\nabla^2\psi + \frac{4\pi^2m^2v^2}{h^2}\psi = 0 \tag{42}$$

This equation can be changed once more and written in terms of the total and potential energies of the system. Since

$$W = K.E. + P.E. = {}^1/_2mv^2 + V$$

or

$$v^2 = \frac{2}{m}(W - V)$$

where

W = total energy of system
$K.E.$ = ${}^1/_2mv^2$ = kinetic energy of particle
$P.E.$ = V = potential energy of particle
m = mass of particle
v = velocity of particle

Equation (42) now becomes

$$\nabla^2\psi + \frac{8\pi^2m}{h^2}(W - V)\psi = 0 \tag{43}$$

and this is the celebrated wave equation of Schroedinger, where ψ is simply a describing function of the problem.

SOLUTION OF THE SCHROEDINGER EQUATION

In order to compare our treatment with the development of the vibrating string it will be of interest to outline the solution of the simple harmonic oscillator. The differential equation is

$$\frac{\partial^2\psi}{\partial x^2} + \frac{8\pi^2m}{h^2}(W - V)\psi = 0 \tag{44}$$

where

ψ = the wave function pertaining to the system
m = mass of oscillating particle

x = coördinate
h = Planck's constant
W = total energy of system
V = potential energy of system $= 2\pi^2 m\nu^2 x^2$
ν = frequency of the motion

Let

$$\alpha = 8\pi^2 mW/h^2;\ \beta = 4\pi^2 m\nu/h;\ z = x\sqrt{\beta}.$$

Equation (44) can be rewritten

$$\frac{d^2\psi}{dz^2} + \left(\frac{\alpha}{\beta} - z^2\right)\psi = 0 \qquad (45)$$

In order to satisfy the asymptotic solution at $z = \pm\infty$ we assume the solution

$$\psi = v \cdot e^{-z^2/2};\ v = f(z) \qquad (46)$$

Differentiating twice and placing the derivatives into (45) yields a differential equation which the variable v must satisfy:

$$\frac{d^2v}{dz^2} - 2z\frac{dv}{dz} + (\alpha/\beta - 1)v = 0 \qquad (47)$$

We shall try a power series solution

$$v = \Sigma a_k z^k \qquad (48)$$

Finding the derivatives dv/dz and d^2v/dz^2 and placing them in equation (47) produces an identity, whose coefficients must be zero. The kth coefficient yields the recursion formula

$$a_{k+2} = \frac{2k + 1 - \alpha/\beta}{(k+2)(k+1)} \cdot a_k \qquad (49)$$

These coefficients can be written in terms of two (a_0 and a_1) and the series v is still an infinite series. In order to be certain that the describing function ψ will go to zero as z approaches infinity, we shall end the series and convert it into a polynomial. We assume that a_k shall be the last term or $a_k \neq 0$. Then $a_{k+2} = 0$ and from (49)

$$a_{k+2}(k+2)(k+1) = (2k + 1 - \alpha/\beta) \cdot a_k \qquad (50)$$

We see that

$$2k + 1 - \alpha/\beta = 0 \qquad (51)$$

or

$$W = (k + {}^1/_2)h\nu \qquad (52)$$

and we see that the demand that the describing function ψ should obey certain boundary relations has brought in the quantum conditions. The similarity in treatment of the present problem of the simple harmonic oscillator with that of the development of the problem of the vibrating string is obvious.

THE RADIAL HYDROGEN EQUATION

Another example of this method is the solution of the radical part of the Schroedinger equation of the hydrogen atom. It can be written

$$\frac{d^2f}{dr^2} + \left(A + \frac{B}{r}\right)f = 0 \qquad (53)$$

where

$f = r \cdot \psi = v(r)e^{-\alpha r}$; α = constant
r = radial distance from proton to electron
ψ = describing function $= \psi(r)$
$A = 8\pi^2 mW/h^2$
$B = 8\pi^2 me^2/h^2$

On finding the first and second derivatives of the function f, placing them into equation (53) gives a differential equation in $v(r)$:

$$\frac{d^2v}{dr^2} - 2\alpha\frac{dv}{dr} + \frac{B}{r}v = 0 \qquad (54)$$

if $\alpha^2 = -A$. Now we assume

$$v(r) = \Sigma a_k r^k \qquad (55)$$

and differentiating twice and inserting the result into equation (54) gives an identity whose coefficients must be zero. A recursion formula for the coefficients appears as usual

$$a_{k+1}(k+1)k = \{2\alpha k - B\} \cdot a_k \qquad (56)$$

Applying the usual argument that the series $v(r)$ must end in order to insure the proper condition at the boundary yields $a_k \neq 0$ and $a_{k+1} = 0$. Or from (56) since $(k+1)k \neq 0$ we find

$$2\alpha k - B = 0 \quad \text{or} \quad W = -\frac{2\pi^2 me^4}{k^2h^2};\ k = 0, 1\ldots \qquad (57)$$

But these values for the total energy W are just the ones found from Bohr's quantum conditions! It is of course clear that an adequate treatment of these problems involves the determination of the wave functions themselves, a topic which we have avoided. But this task was not our aim since we only wanted to show how the questions of atomic structure can be introduced on the basis of wave mechanics.

SUMMARY

A treatment of atomic structure problems on the basis of Bohr theory is outlined which permits a consistent development for various cases such as the hydrogen atom, the linear harmonic oscillator, the hydrogen molecule, etc. In order to introduce the ideas of wave mechanics a short review of the theories of radiation and its interaction with matter follows logically. The dual nature of our ideas of light, as adapted by de Broglie for particles, also helps to bring out the basic aspects of the wave mechanical view. Two mechanical problems —the vibrating string and the rotating shaft—show that large scale systems can be of such nature as to be dependent on integral numbers. The solution of the differential equations of these problems serves as an excellent exercise for further study of atomic and molecular systems since the same method of attack can be used. The Schroedinger equation is derived from the general wave equation of physics, and the solutions of the linear oscillator and the hydrogen atom are briefly summarized, indicating the similarity in treatment of these structures with the mechanical problems mentioned above.

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DISCUSSION OF THE PAPER

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THOSE teaching physical chemistry are presented with a real dilemma, since the majority of undergraduates will find places in the industry without proceeding to graduate schools. The course must, therefore, be designed to meet the needs of these as well as of the relatively few who do go on to graduate work, and of the minute number who intend eventually to specialize in the more purely scientific aspects of physical chemistry. In large institutions classes might well be divided into sections dependent upon ability and inclination, but in the smaller institutions this cannot be done without making sections so small as to be impracticable.

A course in physical chemistry must, therefore, include a rather strong emphasis on what might be termed the classical branches of the subject. Nevertheless, we must be willing to introduce theoretical matter which aids in correlating different phases of the subject. This means that if the introduction of wave mechanics will permit the average student to appreciate interrelationships between various fields it is highly desirable.

As Professor Glockler has pointed out, it is necessary to have some understanding of wave mechanics in order to appreciate modern theories of valency and of chemical binding. From the course in physics the student usually remembers that the vibrating string and certain other physical phenomena can be treated with the use of differential equations and that certain whole-number relationships usually appear when wave equations are used.

It seems to me, however, that it is vitally important to introduce the student to the physical reasons why whole-number relationships and quantum descriptions are necessary in dealing with certain atomic and molecular phenomena. Before one gives any solutions of wave equations the student should have a thorough familiarity with certain simple facts of spectroscopy, of specific heats, of reaction rates, of the photoelectric effect, and of certain other subjects which demand quantum explanations. The average junior in an American university is usually completely lacking in the experimental background which is necessary to comprehend the reasons for introducing wave mechanics.

It is perhaps not worth while to indulge in a detailed treatment of the Bohr atom. It might be described and the objections to it pointed out. Indeed, a brief introduction of the Heisenberg uncertainty principle would help the student to appreciate the difficulties in inelastic atom models. The descriptions of valence forces in terms of exchange and coulombic binding and of resonance scarcely demand any solution of wave equations, but will help the student to appreciate the difference in point of view between classical and atomic systems.

In some ways it would be more useful to introduce the students in elementary physical chemistry to the foundations of statistics than to detailed solutions of wave equations. Use of statistics is becoming well-nigh universal in the treatment of chemical problems and will in no way depend on any particular atom model or system which is used to describe energy states of atoms and molecules.

Thus, while we might agree in the main with the thesis of Professor Glockler that very new developments should be introduced into elementary physical chemistry courses, we must emphasize that it is more important at that stage of the game to develop a real appreciation and feel for physical phenomena than it is to introduce rigorous mathematics.

CHEMICAL WARFARE IN THOSE DAYS

SIR Lyon Playfair (1818–98), student of Graham and Liebig, was an outstanding figure in the chemical and political world. This quotation from his autobiographical notes seems particularly timely now.

"It was fortunate that the Department of Science and Art was founded in 1853, because the Crimean War broke out in the following year and heavily taxed the country. At the beginning of the war I wrote a letter to the Prince Consort, which he forwarded to the Master of the Ordnance, suggesting one or two applications of science to the purposes of war. One was a hollow brittle shell containing phosphorus dissolved in bisulfide of carbon for the purpose of producing conflagration of the enemy's stores or property. The shell contained antimony, so as to make it break on a hard surface. It then scattered the liquid over the objects to be burned, and each drop, on drying, started a new centre of conflagration. As the fumes of phosphorus are apt to put out their own flame, a little beeswax or petroleum was added to prevent this. The Ordnance Department reported against this proposal, and I did not care to push it further; but ten years later the plan with exactly the same materials was adopted and the inventor, who was an officer, received promotion, and I think a decoration. The Fenians have lately used this method of setting property on fire, and tried its effects on one of the Cunard ships.

"The other proposal in my letter was to have a hollow brittle shell containing cyanide of cacodyl. This is an intensely poisonous substance, a few drops of which in a room would poison the occupants. Such a shell going between decks of a ship would render the atmosphere irrespirable, and poison the men if they remained at the guns. This suggestion was considered inadmissible by the military authorities, who stated that it would be as bad a mode of warfare as poisoning the wells of the enemy. There was no sense in this objection. It is considered a legitimate mode of warfare to fill shells with molten metal which scatters among the enemy, and produces the most frightful modes of death. Why a poisonous vapour which would kill men without suffering is to be considered illegitimate warfare is incomprehensible. War is destruction, and the more destructive it can be made with the least suffering the sooner will be ended that barbarous method of protecting national rights. No doubt in time chemistry will be used to lessen the suffering of combatants, and even of criminals condemned to death. Hanging is a relic of barbarism, because criminals might be put to death without physical torture."[1]

—Contributed by Ralph E. Oesper, University of Cincinnati

[1] REID, "Memoirs and correspondence of Lyon Playfair," Harper and Brothers, New York City, 1899, p. 159.

Molecular Models with Free Rotation

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A new type of molecular model is described in which the wooden spheres representing atoms are joined together by snap fasteners which permit free rotation, but at the same time hold the model securely together. Details are given for making such models including methods of obtaining tetrahedral angles for the bonds. Models made in this way serve to increase our understanding not only of structural relationships, but of possible molecular motions.

MOLECULAR models such as those commonly used for instructional purposes in elementary organic chemistry are constructed of wooden spheres held together by short, removable wooden pegs. These "expanded" models, to use a phrase of Hauser's (*1*), are built without a careful regard for the correct internuclear distances although usually an attempt is made to duplicate the tetrahedral angles of the carbon bonds. Such models are not satisfactory because of sticking of the wooden pegs in damp weather, of inability to obtain exact relative sizes and angles, of the mechanical weakness of complicated models, but chiefly because of the inflexibility of models of molecules which in nature actually coil up, uncoil, bend, twist, or undergo other internal molecular motions. More accurate "close-packed" models having more nearly exact relative internuclear distances and atomic sizes such as the Stuart (*2*) (Fisher-Hirschfelder) models

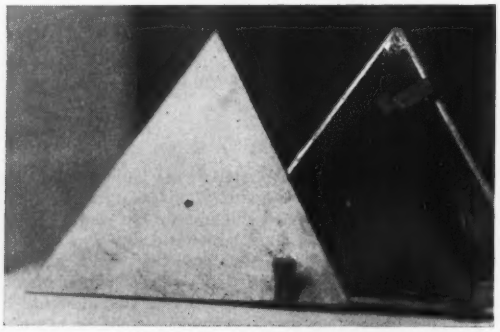


FIGURE 1.—JIG USED TO GUIDE DRILL IN BORING HOLES AT TETRAHEDRAL ANGLE

suffer also from the inability to duplicate molecular coiling and twisting motions; they also fall apart too easily in handling and the metal tapered joints do not always permit the wooden spheres with flat faces to be connected at the correct distance apart. Scattergood (*3*), Seymour (*4*), and Hauser (*1*) have described methods of constructing "close-packed" models of crystals, but in all these models the spheres representing the atoms are fixed rigidly together. Mack (*5*) made a flexible model of a fragment of rubber by joining aluminum spheres on metal axles. While this model successfully illustrated the coiling and uncoiling of rubber when relaxed and stretched, it was not easily constructed or dismantled.

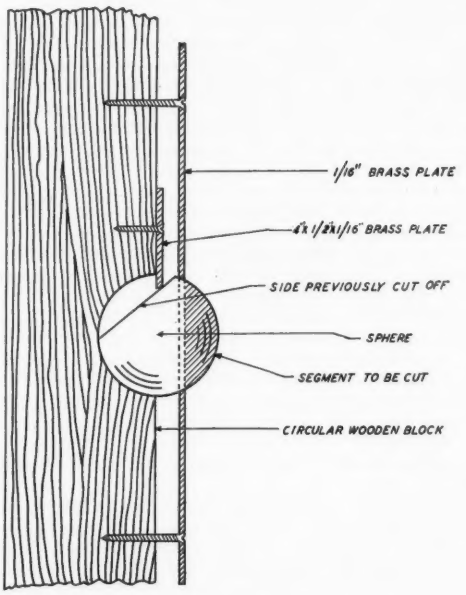


FIGURE 2

In presenting a review of the facts and theories concerning the viscous flow of linear polymeric molecules before the weekly "Journal Club" at Northwestern University one of us desired a molecular model having free rotation about the carbon to carbon bond to illustrate his discussion. Accordingly we conceived the notion of adapting ordinary snap fasteners such as are used on gloves or other types of clothing as the link between the wooden balls representing the atoms.[1] These snap fasteners hold the balls firmly together yet permit internal rotation of the model. We realize, of course, that molecular rotations are not entirely "free" but are hindered by low potential barriers. Snap fasteners could probably be made giving the necessary restriction to the rotational motion, but we have not attempted to include this refinement in our models. We were fortunate in finding a commercial source[2] of

[1] After this method of building molecular models had been worked out, we learned in conversation with a friend that H. S. Taylor and co-workers at Princeton had devised a somewhat similar although not identical system.

[2] The Rau Fastener Company, 19 South Wells Street, Chicago, Illinois. The plug element is called "97$^3/_8$" Nickel Screw Stud" and the socket element "95-Nickel Socket."

snap fasteners in which a wood screw was already built into the plug element and whose socket element contained a hole through which another small wood screw could be inserted. Thus it was easy to prepare the separate atoms for the models by screwing these snap fasteners into holes previously drilled in the wooden balls.

To secure the correct tetrahedral bond angles for the carbon atoms a jig was made (Figure 1) which served as a guide for the drilling of the screw holes; three triangular brass plates of the proper size were soldered together, the fourth side being held in place by spring clips after the wooden sphere had been dropped into the tetrahedron. The small holes in the faces of the tetrahedron permitted the drill to bore the holes in the firmly held wooden balls only at the correct angle. The size of the triangular brass plates and the correct position for the small hole are given by the equations

$$l = 2r \tan \frac{\beta}{2} \cdot \sqrt{3} \qquad (1)$$

and

$$x = r \tan \frac{\beta}{2} \qquad (2)$$

where l is the length of one side of the equilateral triangles constituting the pyramid, β is the tetrahedral angle, r the radius of the wooden sphere to be placed in the tetrahedron, and x the vertical distance from the base of the tetrahedron to the guide holes in each face plate.

It is necessary to make flat faces on the surface of the wooden balls if "close-packed" models are to be constructed according to the method of Stuart[3]; one face on each atom for each bond. As the size of the wooden balls required for the snap fasteners which we used, $1^1/_2$ inches in diameter, was larger than the similar carbon models commercially available, we found it necessary to turn down the balls on a wood lathe. A

FIGURE 3.—ILLUSTRATING THE TURNING DOWN OF THE WOODEN SPHERE TO PRODUCE THE FLAT FACES REQUIRED IN THE CLOSE-PACKED MODELS

spherical depression was cut out of a rotating wooden block into which a ball could be inserted and held in place by a brass plate (see Figure 2). The ball was then turned down to the surface of the plate as illustrated in the photograph in Figure 3. Other faces were cut with the ball held firmly in place with the aid of an auxiliary brass plate (Figure 2).

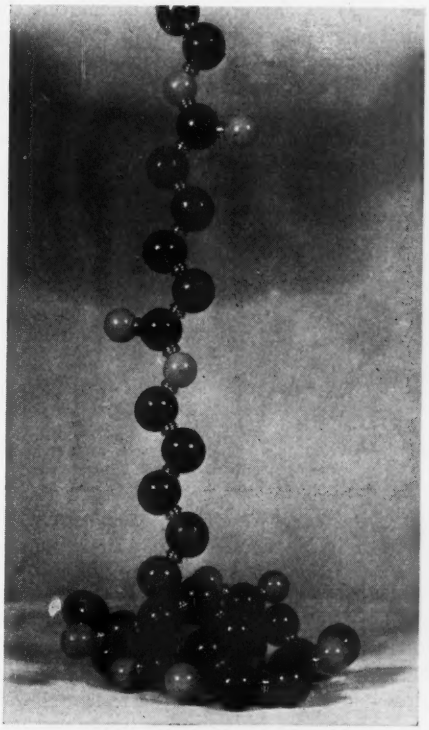


FIGURE 4.—SWIVEL-BOND EXPANDED-TYPE MODEL OF A FRAGMENT OF THE NYLON MOLECULE, WITH HYDROGEN ATOMS OMITTED. THE PHOTOGRAPH DEMONSTRATES THE UNCOILING OF THE MODEL AS IT IS LIFTED UP

The socket section of each snap fastener was countersunk by cutting out a small depression in the wooden

TABLE 1

BOND ANGLES AND RADII USED IN MODEL CONSTRUCTION

Bond	*Internuclear Distance*	*Bond Angle*
C–C	1.54A.	109° 28′ (α)
C=C	1.30	109° 28′ (α) 125° (β)
C (aromatic)	1.40	120° (β)
C≡C–	1.20	180°
C–H	1.08	
C–N	1.47	109° (α)
C–O	1.46	109° (α)
–O–H	1.00	
N–H	1.01	109° (α)
C=O	1.25	

[3] Similar models designed by J. Hirschfelder are sold in this country by the Fisher Scientific Company.

face at the same time that the face was turned down. The screw hole was also drilled in the center of each face while the ball was held on the lathe. Finally the surface was sandpapered, the balls were painted the desired color, and the snap fasteners inserted. Table 1 gives the data taken from Pauling (*6*) and Pauling, Springall, and Palmer (*7*) which were used in calculating the bond angles and internuclear distances for the various types of carbon bonds, and oxygen, hydrogen, and nitrogen bonds. Only two sizes of wooden spheres were available to us, $1^1/_2$ and $1^1/_4$ inches in diameter, so that the spheres in our models do not represent the exact electronic fields of force, but the internuclear distances and bond angles are correct within 1–3 per cent.

In our models one inch represents 1.7A.

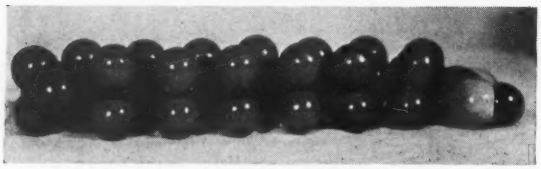


FIGURE 5.—SWIVEL-BOND CLOSE-PACKED MODEL OF PENTADECOIC ACID IN LINEAR FORM

The snap fasteners were modified to prevent rotation in the case of doubly bonded carbon to carbon atoms by driving a wire staple into the sphere through two small holes drilled into the socket element. When the plug part of the snap fastener was pressed into these socket elements, the staple fitted into the screw head in such a way that rotation was prevented.

Figure 4 is a photograph of an expanded type of model of a fragment of the nylon linear polymer, with hydrogen atoms omitted. The long string of atoms, 54 in number, was coiled up in a pile and then lifted up. The pile readily uncoiled and the strength of the snap-

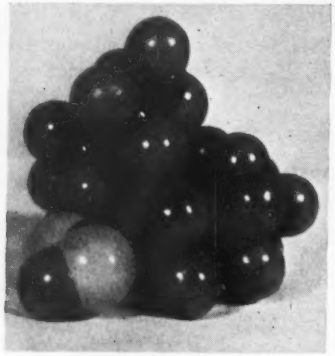


FIGURE 6.—SWIVEL-BOND CLOSE-PACKED MODEL OF PENTADECOIC ACID COILED UP

fastened joints was sufficient to support the weight of a large number of atoms. Figure 5 is a close-packed model of pentadecoic acid in the linear form while Figure 6 is the same model coiled up. One great advantage in building and studying molecular models rests in the aid such studies give in recognizing and discovering spacial relationships which would otherwise

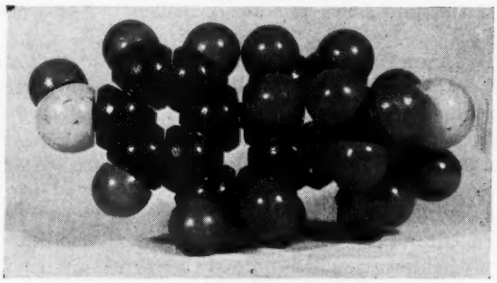
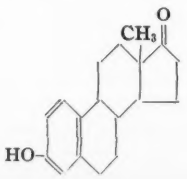


FIGURE 7.—SWIVEL-BOND CLOSE-PACKED MODEL OF THE FEMALE SEX HORMONE, THEELIN

be either completely overlooked or only partly understood. As an example consider the two sex hormones, theelin (female)



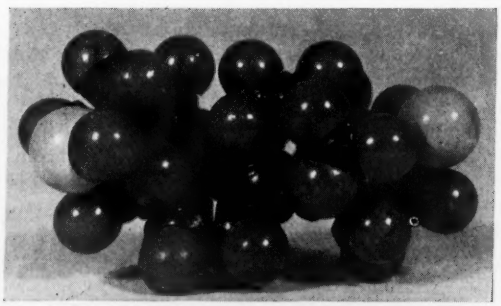
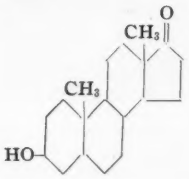


FIGURE 8.—SWIVEL-BOND CLOSE-PACKED MODEL OF THE MALE SEX HORMONE, ANDROSTERONE

and androsterone (male)



The plane structures look extremely similar yet when the close-packed models are built (Figures 7 and 8) marked differences can be noticed, not only in the peripheral appearance of the molecules, but in their relative structural rigidity. Furthermore, the tight-

ness with which the methyl groups are held in the molecule can be easily seen; they are not even "free" enough to rotate.

In conclusion we wish to express our sincere thanks to Professor R. G. Bigelow of the Northwestern Technological Institute for his suggestions concerning the types of jigs to use and for access to the wood lathes of the Engineering School.

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SEMIMICRO CHEMISTRY FOR THE BEGINNING STUDENT

VERNON E. WOOD and H. RAWORTH WALKER, Jr.
Mars Hill College, Mars Hill, North Carolina

IN THE spring of 1940 Mars Hill was building a new science hall. The entire fourth floor measuring 156 by 64 feet was allotted to chemistry and physics. The laboratory for beginning students in chemistry was a room 30 by 60 feet. It was necessary that this room provide individual lockers for 240 students. We had desks made to special specifications with lockers one foot wide for each student's equipment. We allotted 10 square feet of working space for each student in a section. In order to take care of the equipment of each student in a cabinet one foot wide we decided to use semimicro methods wherever they were possible from the beginning of the first-year course. After correspondence with a dozen of the largest textbook publishers in America we found that there was no available laboratory manual providing for semimicro technics and equipment. The only thing left for us to do was to write such a manual for ourselves.

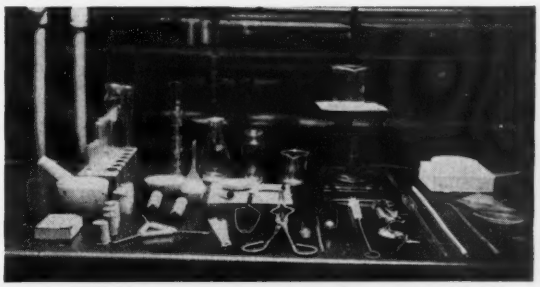
The manual which we prepared covers work for general chemistry, a little simple organic, hundreds of spot-plate tests for ionic interactions, and systematic qualitative analysis.

We have used this manual during the present school year in four laboratory sections with a total of 150 students in order to study the reaction to this type of work in comparison with that of student sections for the past two decades using macro methods. We have also used a very popular macro method manual in one of our sections this year. Our observation is that students enjoy the semimicro method.

A beginning student is likely to be sloppy and careless in handling of equipment and chemicals. We have found that the introduction of semimicro technics at the beginning of the course tends to make students much more careful in their procedures before they reach qualitative analysis.

Another item of importance in our laboratory is the saving in cost of equipment and chemicals. We estimate that we have saved almost 75 per cent in the cost of chemicals and 30 per cent in the cost of equipment without sacrificing any valuable student experience in beginning chemistry. Some new equipment was necessary but the extra cost of this was more than offset by savings in other items. For instance, enough was saved on filter paper alone to pay for six new Wilmar centrifuges. Materials such as test tubes, graduates, thistle tubes, and other equipment which must be replaced are so much less expensive in the sizes used in semimicro procedures that the lower cost of replacement gives the student a large annual saving.

For shelf reagents, bottles equipped with medicine droppers and glass-stoppered indicator dropping bottles were used exclusively. Many of the tests are run on spot plates.



EQUIPMENT FOR THE BEGINNING COURSE

This work was not meant to be revolutionary in the type of experiments used. The regular classical experiments with some alterations and changes have been performed, with the small equipment of the semimicro technics rather than the larger equipment of the old macro methods.

Those students repeating the course this year because of failures last year have all been enthusiastic about the change from macro to semimicro. They say that they can accomplish more in a shorter time.

A History of the Match Industry[1]

M. F. CRASS, JR. *Washington, D. C.*

PART IX—PHOSPHORUS NECROSIS

THE subject of phosphorus necrosis is definitely a part of any discussion concerning the history of the match industry, and the elimination of this industrial disease with its ghastly and disgusting effects stands out as a tribute to the research workers who made possible the development of the modern non-poisonous friction match.

The appearance of phosphorus necrosis was first reported by Lorinser of Vienna, who in 1845 published a paper recording cases of the disease which occurred as early as 1839 (*1*).

In 1845 a New York surgeon published a pamphlet giving the case histories of nine serious cases, one of which required the removal of the entire jaw (*2*).

In 1863 an American patent (*3*) was granted to two Englishmen, Bell and Higgins, for a method of dipping splints in phosphorus composition which obviated the necessity of the dipper standing over the hot composition. The following account taken from the patent specification shows the foothold that had been gained by the disease, even at this early date:

"This method removes the liability which at present exists of the workmen contracting the disease, *which is now common* among lucifer match makers in consequence of manipulating the phosphorus compounds."

In 1864, twelve additional cases, all of them serious, were recorded in a letter written to a New York newspaper. One of these cases was that of a young girl working in a match factory in New York City, which is described as follows (*4*):

"The girl had a tooth extracted and was poisoned by the phosphorus fumes which entered the cavity. Necrosis was introduced, which extended to either side of the jaw bone, points of discharge soon appearing upon the surface of the skin. This went on for two years, minor operations being made at various times to remove diseased portions of bone. At the end of two years it was found necessary to resort to an extreme operation, during which the entire jaw bone, from side to side, was removed and the tongue fastened down to prevent strangulation until such time as the parts should heal. This young girl is now terribly deformed, can only take liquid nourishment hereafter for subsistence, and all the beauty of life is destroyed to her."

A later account (*5*) states (1877):

"Continual association with phosphorus in match factories gives rise to a disease known as 'caries of the jaw bones.' In some of the small and poorly managed factories the men and children are never free from the fumes; their clothing and breath are luminous in the dark, and in the daytime white fumes may be seen escaping from them when they are seated by the fire."

According to Dr. John B. Andrews (*6*), the dangers from phosphorus were manifold, some being general, others local. His discussion follows:

"The most general effect noted among match workers was anemia, caused by daily breathing of the phosphorus fumes and continual contact with small particles of the element, resulting in a gradual lowering of the worker's vitality, thus inviting other diseases. The local effect resulted in necrosis of the jaws, caused by absorption of phosphorus through the teeth or gums, generally through damaged teeth. Inflammation is set up, which if not quickly arrested, extends along the jaw killing the teeth and bones. The gums become swollen and purple, the teeth loosen and drop out, and the jawbones slowly decompose and decay, passing away in the form of nauseating pus which sometimes breaks through the neck in the form of an abscess; or, if not almost continually washed out, oozes into the mouth where it mixes with the saliva and is swallowed. Treatment is largely preventative, but when the disease is once established a serious operation is often the only means of arresting the progress of decay, requiring the removal of one or both jaws, with a possibility of death."

Another account (*7*) states:

"The disease occurs only in chronic form, occasioned by the absorption of very minute particles of poison over a period of months or years. Symptoms of the disease sometimes appear long after relinquishment of the occupation. Chronic poisoning uniformly affects the bones of the face, beginning with inflammation and sclerosis of the bones and periosteum; then by extension of the suppurative process, necrosis results. Swelling and ulcerations on the gums and mucous membrane, pain even in sound teeth, loosening and falling out of teeth, and infiltration of board-like hardness occurs in the soft parts surrounding the jaw; suppuration and destruction of the jaw bone, with numerous fistulous channels which burrow through the cheek.

"The under jaw is more likely to become infected than the upper, and no new bone is formed. The palatal and orbital bones may be attacked, with ulceration and shrinkage of the eyeball. By extension of the inflammation along the blood vessels there results meningeal inflammation and cerebral abscess. There is remarkable brittleness of the bones, decline of appetite, pallid complexion, diarrhea, emaciation. Sometimes there is amyloid degeneration of the abdominal organs. Death by sepsis."

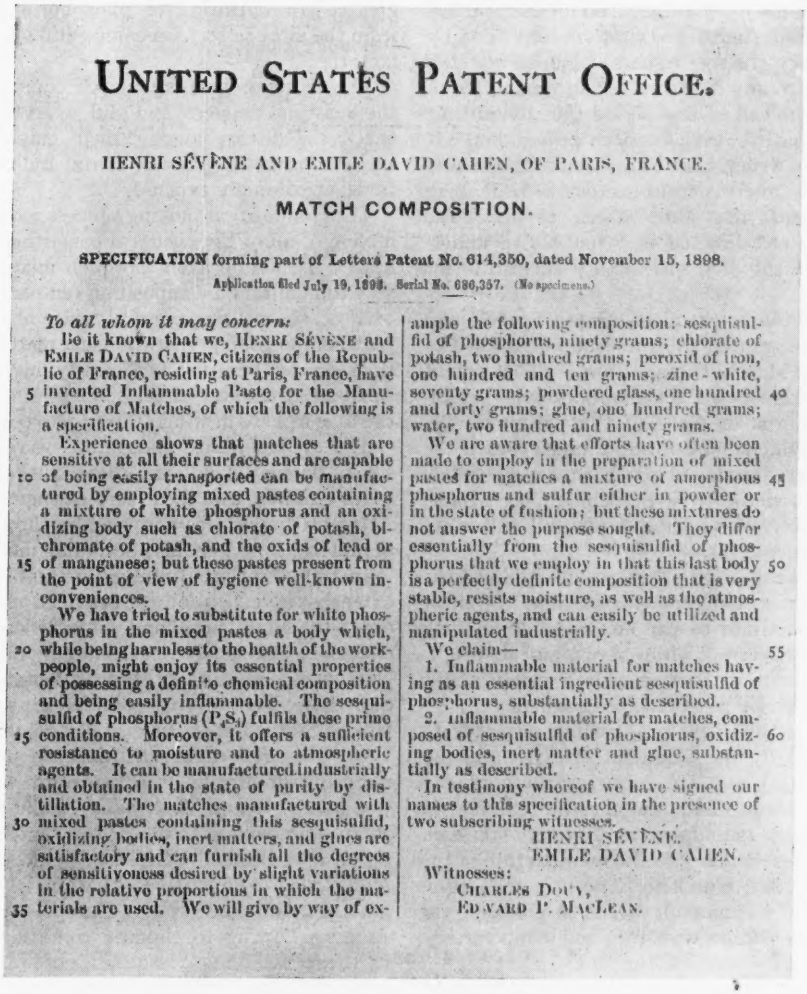
Within eleven years after the phosphorus match had been introduced, governmental investigators in foreign countries were studying the conditions under which the disease originated (*6*). Recognizing the fact that poorly ventilated workrooms and factories contributed in a large measure to the seriousness of the situation, many of these governments promulgated stringent regulations regarding building and ventilation requirements, and set up thorough and elaborate inspection systems and health regulations, which resulted in the elimination of a great many of the smaller factories which operated in damp and poorly ventilated basements and drove others into light airy buildings.

Some countries required periodic dental and medical examinations of the workers and the furnishing of isolated lunch rooms and free mouth wash, soap, and towels. But so serious were the results of the disease, even under such thorough inspection and regulation, that the leading European countries soon began to abandon attempts to regulate, and passed laws forbidding the use of white phosphorus for match-making purposes.

[1] Continued from the August, 1941, issue.

Finland, in 1872, was the first country to prohibit such use, followed by Denmark in 1874. France was the next country to prohibit white phosphorus, in 1897, followed by Switzerland in 1898 and Holland in 1901. Sweden prohibited domestic use of white phosphorus matches but permitted them to be made for exportation to other countries.

Because of the difficulties experienced in eliminating



UNITED STATES PATENT OFFICE.

HENRI SÉVÈNE AND EMILE DAVID CAHEN, OF PARIS, FRANCE.

MATCH COMPOSITION.

SPECIFICATION forming part of Letters Patent No. 614,350, dated November 15, 1898.

Application filed July 19, 1898. Serial No. 686,357. (No specimens.)

To all whom it may concern:

Be it known that we, HENRI SÉVÈNE and EMILE DAVID CAHEN, citizens of the Republic of France, residing at Paris, France, have invented Inflammable Paste for the Manufacture of Matches, of which the following is a specification.

Experience shows that matches that are sensitive at all their surfaces and are capable of being easily transported can be manufactured by employing mixed pastes containing a mixture of white phosphorus and an oxidizing body such as chlorate of potash, bichromate of potash, and the oxids of lead or of manganese; but these pastes present from the point of view of hygiene well-known inconveniences.

We have tried to substitute for white phosphorus in the mixed pastes a body which, while being harmless to the health of the workpeople, might enjoy its essential properties of possessing a definite chemical composition and being easily inflammable. The sesquisulfid of phosphorus (P_4S_3) fulfils these prime conditions. Moreover, it offers a sufficient resistance to moisture and to atmospheric agents. It can be manufactured industrially and obtained in the state of purity by distillation. The matches manufactured with mixed pastes containing this sesquisulfid, oxidizing bodies, inert matters, and glues are satisfactory and can furnish all the degrees of sensitiveness desired by slight variations in the relative proportions in which the materials are used. We will give by way of example the following composition: sesquisulfid of phosphorus, ninety grams; chlorate of potash, two hundred grams; peroxid of iron, one hundred and ten grams; zinc-white, seventy grams; powdered glass, one hundred and forty grams; glue, one hundred grams; water, two hundred and ninety grams.

We are aware that efforts have often been made to employ in the preparation of mixed pastes for matches a mixture of amorphous phosphorus and sulfur either in powder or in the state of fushion; but these mixtures do not answer the purpose sought. They differ essentially from the sesquisulfid of phosphorus that we employ in that this last body is a perfectly definite composition that is very stable, resists moisture, as well as the atmospheric agents, and can easily be utilized and manipulated industrially.

We claim—

1. Inflammable material for matches having as an essential ingredient sesquisulfid of phosphorus, substantially as described.

2. Inflammable material for matches, composed of sesquisulfid of phosphorus, oxidizing bodies, inert matter and glue, substantially as described.

In testimony whereof we have signed our names to this specification in the presence of two subscribing witnesses.

HENRI SÉVÈNE.
EMILE DAVID CAHEN.

Witnesses:
CHARLES DOUY,
EDWARD P. MACLEAN.

PATENT GRANTED TO SÉVÈNE AND CAHEN

Russia attempted in 1892 to tax white phosphorus matches out of existence, and in 1905 succeeded in total elimination by doubling the 1892 tax. Belgium, Austria, Norway, and Spain all passed such stringent restrictions against the use of white phosphorus that its application in match manufacturing became negligible, and safety matches were widely used in place of the poisonous variety containing white phosphorus.

Some of the countries fixed the maximum amount of phosphorus that could be used, the allowable maximum quantity being so low that it was not possible to make satisfactory friction matches under the laws, and much illegal manufacturing went on in small establishments. The net result, however, was to force the public to use the non-poisonous safety match. In 1895, phosphorus matches in countries that had an export trade dependent on them, the International Association for Labor Legislation called an international conference at Berne in 1906 to consider the matter. As a result of this conference, an international treaty was drawn, which provided for the absolute prohibition of the manufacture, importation, or sale of matches containing white phosphorus. Signatories to the treaty were France, Denmark, Luxemburg, Italy, Switzerland, Holland, and Germany. England did not sign the treaty (having in operation a very strict set of regulations and an excellent inspection system) until 1908, when the British White Phosphorus Match Prohibition Act was passed. A clause was inserted in this act making phosphorus sesquisulfide available to all match

manufacturers upon payment of reasonable royalties to the owner of the patent. The act became operative on January 1, 1910.

In 1872 the French Government, in an effort to bolster its tax revenue, established the first state match monopoly. This monopoly, established for the primary purpose of obtaining funds, was first accomplished by giving one company the sole right to produce matches for a period of 20 years, in return for an annual fee of $3,700,000. At the end of this period the government assumed active control over all match production. It was soon found, however, that compensation payments to match workers suffering from necrosis were making serious inroads into the state match profits. The government therefore directed its scientists to undertake the development of a satisfactory substitute for white phosphorus.

In 1898 two French chemists, Henri Sévène and Emile Cahen, were granted an American patent for "An Improvement in Match Composition." The patent was based upon the use of the non-poisonous sesquisulfide of phosphorus in place of the poisonous elemental form, and included a formula under which the new matches were made. Phosphorus sesquisulfide (P_4S_3) was first prepared by a Frenchman, Le Moine, in 1864, by heating white phosphorus and sulfur together in the absence of air.

The successful adaptation of the sesquisulfide to the match manufacturing industry was perhaps the most outstanding contribution to the history of firemaking since Brandt's discovery of phosphorus, and its use as the active ingredient in friction match compositions was rapidly adopted by most civilized countries.

The American rights to the sesquisulfide patent were purchased in 1900 by the Diamond Match Company for the sum of $100,000. The French state monopoly began producing sesquisulfide matches in 1898 and in 1900 a large British manufacturer, Bryant and May, was granted a license and began the manufacture of the non-poisonous friction matches. The original sesquisulfide match, the formula for which is given in the reproduction of the patent, was of the single-dip variety.

Introduction of the Sesquisulfide Match in the United States

While a majority of the European countries had either prohibited the use of white phosphorus matches by the year 1900 or had made substantial reductions in the amounts consumed, and had practically eliminated their use by 1906 following the treaty of Berne, the United States continued to use them in increasing quantities as prices became lower and distribution more widespread. No noticeable effort was apparently made to utilize the sesquisulfide patent on a large scale.

In 1907 the double-dip match with its extremely sensitive tip and relatively inert base was placed upon the market by a small match firm located in Michigan (*6*). Previously patented but little used until after the patent had expired, the double-dip match won instant popularity and quickly supplanted the single-dip parlor match in many American homes. While the benefits derived were substantial in so far as increased safety from fires was concerned, the additional amount of phosphorus in the tip served to accentuate the poison hazard to the match factory employee, because of the greater concentration of phosphorus fumes resulting from the more potent tip composition used in the match factories.

The more progressive match companies recognized the existing dangers and did everything possible to check the disease among their employees, requiring them to submit to periodic dental and medical examinations, at company expense.

The composition-making process required a thorough mixing of all of the chemical constituents of the match head. To obtain such thorough mixing, it was necessary to maintain a composition temperature in excess of 44.1°C., the melting point of white phosphorus, during both composition preparation and match-dipping operations—a temperature sufficiently high to vaporize a substantial amount of phosphorus and to contaminate the atmosphere in which the employees worked.

The evils of white phosphorus were recognized outside of the match industry, due to the fatal poisonings of small children who died from eating the match heads. Attempted abortions and suicides through the medium of match eating were also becoming more widespread.

In 1908 the United States Bureau of Labor began an extensive investigation of American match factories in order to obtain first-hand information relative to the effects of phosphorus poisoning upon match factory employees. Results of this investigation, which required two years for its completion, were published in United States Labor Bulletin No. 86, issued in January, 1910. The report revealed that a non-poisonous, commercially practicable substitute for white phosphorus was available and that many of the match manufacturers were willing to use it, but that the slightly additional cost entailed by its use would place them in an unfavorable competitive situation. Claims that such matches, while successful in Europe, could not be used in America "owing to climatic conditions" were refuted by the fact that many thousands of boxes of satisfactory non-poisonous strike-anywhere matches had been placed on the market, several years earlier, by a domestic manufacturer. The vast bulk of the public, slow to react to the occupational hazard involved in the industry, did not demand the non-poisonous match, which cost somewhat more than the type they were already using.

The investigation revealed serious conditions among match factory employees, and disclosed many remote cases of "phossy jaw" as the disease was commonly called. The report ran, in part, as follows:

> "The investigation of 15 out of our 16 match factories in 1909 conclusively proved that in spite of modern methods phosphorus poisoning not only occurs in this country, but exists in a form so serious as to warrant legislative action to eliminate the disease. Sixteen definite cases were discovered by government agents who visited the factories and it was learned that many others occurred.
>
> "An investigation into the homes of workers of three factories

revealed 82 cases. In two factories, 8 cases occurred early in 1909. In one of the most modern factories, 40 cases were recorded since 1880. Of this 40, fifteen lost one or both jaws and several died. In another factory, 21 cases occurred, six of which were in 1909."

Investigators encountered many obstacles in getting information, company officials in some cases and workers in others being hesitant to divulge information concerning all known cases of necrosis. Women especially were secretive, as they regarded their former match factory employment as a stigma and in certain cases denied that they had ever worked in such an establishment.

According to the report 65 per cent of all the employees were exposed to the disease, women and children being exposed more than male employees. (Of the 3591 persons employed in the 15 factories, 2024 were men, 1253 women, 121 boys under 16 years of age, 193 girls under 16 years.)

The report further states:

"The company owning the patent rights for phosphorus sesquisulfide, believing this material to be a remedy for the prevailing trouble, has expressed willingness to permit its use by other match manufacturers on equal terms, provided the use of white phosphorus is prohibited by law. Other manufacturers have agreed to this if such law is passed. When everything is considered it appears almost criminal to permit longer the use of a poison for which there is a harmless substitute."

As a result of the investigation of the Bureau of Labor, and through the efforts of the American Association for Labor Legislation, Congressional hearings were begun on December 16, 1910, before the Ways and Means Committee of the House of Representatives.

In his annual message to Congress on December 6 of the same year, President Taft said:

"I invite attention to the very serious injury caused to all those who are employed in the manufacture of phosphorus matches. The diseases incident to this are frightful, and as the matches can be made from other materials entirely innocuous, I believe that the injurious manufacture could be discontinued and ought to be discontinued by the imposition of a heavy federal tax. I recommend the adoption of this method of stamping out a very serious abuse."

It was evident that no law could be passed, as in Europe, prohibiting the manufacture of white phosphorus matches, since the Supreme Court had previously ruled that Congress would have no power to prohibit the manufacture of an article within a state. The commerce clause within the Constitution could be invoked to prohibit the transportation of white phosphorus matches in interstate commerce, but this would not prohibit the making of matches that were consumed within the same state, so other means had to be found.

As a result of extended hearings, the Ways and Means Committee issued its report recommending that a tax be placed upon white phosphorus matches. This report, accompanying H.R. 20,842, "A Bill to Provide for a Tax upon White Phosphorus Matches and for other Purposes," was discussed in the House of Representatives and the bill was passed, then referred to the Senate Finance Committee, which adopted it and reported it back to the Senate without amendment and with the recommendation that it be passed. The bill (Public No. 118) was approved by the Senate on April 9, 1912, regulations for enforcement becoming effective on July 1, 1913.

The bill placed a prohibitive tax of two cents per hundred upon all white phosphorus matches made in this country, and required that they be packaged in quantities of 100, 200, 500, 1000, and 1500. Importation was prohibited after January 1, 1913, and exportation after January 1, 1914. In 1911, shortly after the Congressional hearings had begun, the Diamond Match Company deeded the sesquisulfide patent to the public, and made available to other manufacturers the original formula of Sévène and Cahen (*8*).

That phosphorus sesquisulfide was available for satisfactory use in place of white phosphorus at this time is indicated by a patent granted in 1913 (*9*). This patent, filed on October 16, 1912, proposed the use of sesquisulfide in place of red phosphorus as a striking surface on safety match boxes. Claiming that red phosphorus was unreliable, that it often contained white phosphorus, and that it was liable to explode or to ignite violently, the patent specification reads in part as follows:

"Phosphorus sesquisulfide is a definite, stable, compound, which when properly prepared not only is free from white and yellow phosphorus and other poisonous impurities, but is less liable to explode violently when being manipulated, than red phosphorus."

Carrying on the precedent for safety that had been set by the outlawing of white phosphorus, various states began to pass impregnation laws which prohibited the sale of matches whose splints had not been treated chemically to prevent afterglow.

With an adequate relatively cheap supply of nonpoisonous matches available in practically every civilized country, it would appear almost unbelievable that white phosphorus matches were still being used in certain territories up until 1939. That such use persisted until this late date is shown by the passage of an Egyptian law, signed by King Farouk on September 8, 1939, prohibiting under penalty the manufacture, sale, and importation of matches containing white or yellow phosphorus (*10*).

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A Demonstration of Adsorption

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THE adsorption of complex ammonia ions on silica gel offers several distinct advantages for exhibition purposes. Among these are: the speed, specificity, and magnitude of the adsorption are high; several complex ammonia ions are highly colored and the removal of the color in the adsorption process is easily observed; silica gel itself is colorless and transparent so that the adsorption process results in vivid coloration of the adsorbent; and the materials and apparatus are conveniently available in most laboratories.

The apparatus (Figure 1) is mounted on a tall ring stand and is constructed as follows: The adsorbent material, activated silica gel,[1] is supported on glass wool

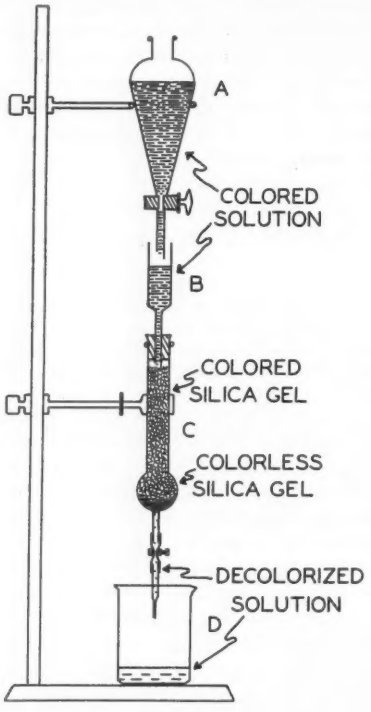

FIGURE 1

in a 25-cm. straight drying tube mounted vertically. A capillary glass tip and screw clamp assembly controls the rate of flow of liquid through the system. A carbon filter funnel is inserted through a rubber stopper in the upper end of the drying tube. The apparatus is completed by mounting a separatory funnel, preferably of the Squibb short stem type and of at least 250-ml. capacity, above the drying tube assembly, and placing a beaker or flask as receiver beneath the outlet.

The separatory funnel is filled with a solution containing a colored complex ammonia ion, such as that of copper (blue), nickel (blue or violet), cobalt (red), or others. All such compounds are highly adsorbed.[2] The solutions are easily prepared in most cases by adding ammonium hydroxide to a dilute solution of the metallic salt, *e. g.*, cupric nitrate, until a slight excess is present as shown by the dissolving of the hydroxide precipitate and the formation of a clear, colored solution. The color should not be too intense, since the decolorization may not be complete in too concentrated solutions. The solution is allowed to drip from the funnel into the carbon filter funnel until the latter is about two-thirds full, and is kept at this level by adjusting the outflow into the receiver so that it drips at the same rate.

An interesting feature of this demonstration is the fact that the silica gel becomes intensely colored at the top of the adsorbent tube, and the coloration decreases continuously until in the lower region little or no coloration is detected. Since the silica gel always assumes the color of the original solution, it is evident that the ion is adsorbed without decomposition. Simple tests on the original and the decolorized solutions may be made to prove that almost complete removal of the metallic ammonia complex is achieved.

The following spot tests are convenient for this purpose. The tests for copper, cobalt, and nickel are carried out on a white surface, such as a drop reaction plate, porcelain dish, drop reaction paper, or filter paper. The test for silver, a colorless solution, is best performed on a black surface or in a small test tube.

Test for Copper. To one to two drops of solution, acidified with acetic acid, are added two drops of 10 per cent potassium ferrocyanide solution. A red to red-brown precipitate of cupric ferrocyanide indicates copper.

Test for Cobalt. To one to two drops of solution, acidified with acetic acid, are added two drops of a saturated solution of α-nitroso-β-naphthol in 50 per cent acetic acid. A red-brown precipitate indicates cobalt.

Test for Nickel. To one to two drops of solution are added one to two drops of a one per cent alcoholic solution of dimethylglyoxime. A bright red precipitate of nickel dimethylglyoxime indicates nickel.

Test for Silver. A few drops of solution are slightly acidified with HNO_3, and two to three drops of 1:1 HCl are added. A white precipitate of AgCl indicates silver.

Several of these systems, each one employing a different colored ammonia complex ion as solute, may be lined up side by side to make a very colorful and instructive exhibit.

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An Apparatus to Demonstrate the Continuous Manufacture of Rayon

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ONE of the exhibits which attracted most attention at a recent "Open House" was a miniature plant for the manufacture of rayon. Washburn (*1*) and Scharf (*2*) have previously described the preparation of rayon threads. The present apparatus produced a lustrous, uniform-diameter fiber of cellulose rayon, and operated continuously for several hours. Filaments as long as forty meters and capable of suspending a 100-gram weight have been made. The plant can be constructed at a low cost.

The apparatus was arranged as shown in the line drawing and accompanying photograph. The cuprammonium process was used in preference to the viscose process because the spinning solution is much easier to make. Students should be advised, however, that four-fifths of our rayon today is made by the viscose process.

APPARATUS FOR DEMONSTRATING THE CONTINUOUS MANUFACTURE OF RAYON

SPINNING SOLUTION

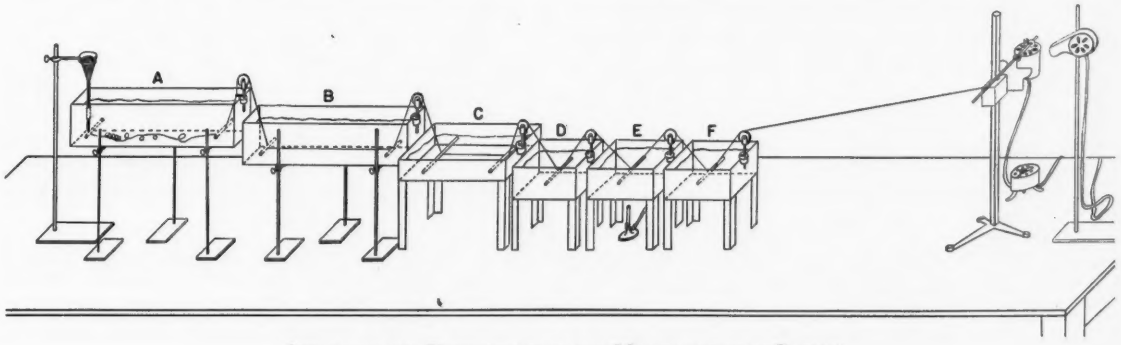
Schweitzer's Reagent was prepared by dissolving 60 g. of cupric hydroxide in one liter of 28 per cent ammonia. Cupric hydroxide is conveniently obtained by precipitation with ammonia from cupric sulfate; it is essential that this operation, as well as the drying on a porous plate, be conducted at low temperature to prevent conversion into cupric oxide. Thirty grams of cotton were pulled into rope form and cut into sections one cm. in length. These were dissolved in the liter of reagent by mechanical stirring, about three hours being required. The mixture was filtered through glass wool, diluted with an equal volume of 28 per cent ammonia, and protected from light.

COAGULATION

The spinning solution was placed in an ordinary funnel to the stem of which was attached a finely drawn capillary bent at right angles; an orifice diameter of 0.7 mm. was found to work well. Smaller orifices produced a single filament which was too weak, while too large an orifice produced a weak, hollow thread. The solution flowed from the capillary into a solution containing 10 per cent glycerin by volume, and 33 per cent sodium hydroxide by weight. The concentration of this solution, as well as that of the acid and soap solutions, was that recommended by Scharf (*2*). The coagulating bath (*A*) as well as the first wash bath (*B*) should be as long as possible; in the present setup they were 75 cm. long.

SUBSEQUENT BATHS

From the coagulating bath the thread was fed under a glass rod held in place by rubber policemen and over a well-greased bakelite pulley, held in place by a rubber stopper, into bath *B*. All the baths were similarly equipped. Varying the position of the glass rods controls the time the filament remains in the bath.



APPARATUS FOR DEMONSTRATING THE MANUFACTURE OF RAYON

Bath *B* was tap water, which should preferably be continuously renewed.

Bath *C* was two per cent sulfuric acid.

Bath *D* was tap water.

Bath *E* was one per cent soap and one per cent glycerin, and was heated to about 70°C.

Bath *F* was tap water.

DRYING AND RATE OF FLOW

From bath *F* the thread was drawn for about one meter through the air and wound upon a glass rod revolving in the chuck of a variable speed stirring motor. While it was moving through the air the filament was dried by a blast of hot air from a hair-dryer.

The speed at which the thread can be drawn through the baths depends on the diameter of the thread and the length of the baths. It should be removed from the acid bath as soon as it is decolorized. Under favorable conditions the plant ran without interruption for periods of two hours. When the thread broke it could conveniently be knotted and the process continued. Due to the friction of the rods and pulleys the thread was stretched as it passed from bath to bath until the diameter of the final product was approximately 0.3 mm.

Further interest can be added to the process by dyeing the dried thread. A direct cotton dye, such as Congo Red, is recommended.

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A QUALITATIVE SEPARATION OF COPPER AND CADMIUM

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MIXTURES of copper and cadmium may be separated quantitatively by precipitation of copper as cuprous thiocyanate. The metal is precipitated from hydrochloric or sulfuric acid solution in the presence of an excess of sulfurous acid (*1, 2, 3*). The reaction is as follows:

$$2CuSO_4 + 2KCNS + NaHSO_3 + H_2O \rightarrow Cu_2(CNS)_2 + K_2SO_4 + H_2SO_4 + NaHSO_4$$

It has occurred to the author that this well established precipitation might also be useful in the separation of copper and cadmium in the qualitative scheme.

The method was tested on a number of solutions containing the cations of Group II. The analyses were made in the usual manner through the point where bismuth is precipitated with ammonium hydroxide and the solution is filtered.

The deep blue filtrate was acidified with acetic acid and treated with 20 ml. of $N/10$ potassium thiocyanate for each 100 mg. of copper present. A 0.5-g. portion of sodium bisulfite was added; the solution was boiled for about one minute and filtered while hot. The clear filtrate was made basic with ammonium hydroxide and treated either with hydrogen sulfide or with a few drops of ammonium sulfide or polysulfide solution. The precipitates were yellow to orange in color with a faint greenish cast. In no case was the color of the cadmium sulfide obscured.

It is necessary to precipitate cadmium from basic solution due to the decomposition of sulfurous acid by hydrogen sulfide with separation of sulfur. If desired, the ammoniacal precipitate can be filtered, washed, dissolved, and reprecipitated from acidic solution. The ammonium polysulfide treatment has an advantage in that it will not precipitate traces of the tin subgroup which may be present.

According to the equation, each 100 mg. of copper require for precipitation 153 mg. of potassium thiocyanate and 82 mg. of sodium bisulfite. An excess of thiocyanate does no harm up to a concentration in the copper-cadmium solution of about 9 g. KCNS per 100 ml. In greater concentration the cuprous thiocyanate is largely dissolved. It reprecipitates when the solution is diluted and boiled. Large excesses of sodium bisulfite have no ill effects. The dilute acetic acid solution liberates only a very little sulfur dioxide into the atmosphere even on boiling. No reasonable excess of acetic acid affects the separation. The precipitate of cuprous thiocyanate filters easily and rapidly. Using ordinary qualitative paper it is only occasionally necessary to refilter.

Of the solutions analyzed, the following is probably the most significant. It contained in each 10 ml.: As, 50 mg.; Sb, 50 mg.; Sn, 50 mg.; Hg, 100 mg.; Pb, saturated with $PbCl_2$; Bi, 100 mg.; Cu, 100 mg.; Cd, 10 mg. A 10-ml. portion was analyzed. One-half of the bismuth filtrate gave a final solution containing a slight but distinct yellow cadmium sulfide precipitate.

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The Reactive Paraffins

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MOST of us emerge from our first year of organic chemistry convinced that the paraffin hydrocarbons are unreactive and therefore quite uninteresting substances. Organic textbooks commonly dismiss the subject with the brief statement that they are highly refractory and do not react with the ordinary laboratory reagents. This conclusion is perhaps somewhat justified in that the prevailing definition of "reactive" is usually applied to such substances as diazonium compounds and Grignard reagents, and it is certainly true that the paraffins do not show comparable reactivity.

Recently we have begun to realize that the paraffins are neither inert nor uninteresting. Their reactions are not the conventional type conducted in the usual laboratory flasks nor are the products often obtained in pure crystalline form. Even when the reactions are carefully controlled, which in itself is an achievement, mixtures are encountered which may require elaborate methods of separation. Most of the developments in paraffin chemistry have arisen through the persistent efforts, over a period of years, of industrial laboratories to utilize the gigantic quantities of paraffins today employed mainly as fuel. We shall consider a few of these developments which have approached the production stage.

Natural gas, available in astronomic quantities, consists almost entirely of paraffins. Three trillion cubic feet of gas were produced during one year (*1*), and of this about 433 billion cubic feet were wasted, since interest is usually centered upon the accompanying liquid petroleum. Gas consists of paraffins from methane up to and including the pentanes, the percentage of each type present in the gas decreasing as we ascend the series. They may be easily separated from each other by distillation under pressure—a type of operation which has become routine for the gas industry. By this method it is possible to obtain almost complete separation of the paraffins as high as those containing not more than four carbon atoms. Although it is possible commercially to separate normal from isobutane, above this point it becomes increasingly difficult to isolate pure paraffins because of the many isomeric possibilities for each number of carbon atoms (*2*). Even with only seven carbons it is possible to have nine isomers, and with thirty carbons there are over four million possibilities. For this reason the bulk of the work on paraffin chemistry has been confined to compounds containing less than six carbon atoms.

Liquid paraffins are more difficult to prepare pure from petroleum due to the large number of isomers present. There are, however, several special crude oils which yield straight-chain hydrocarbons in fairly high concentration. From Michigan crude may be obtained normal heptane of a fair degree of purity (*3*); it has even been suggested that this crude oil be reserved for chemical uses, stocks of more conventional composition being used for gasoline. Fractionation of Pennsylvania crude yields a cut boiling above kerosene, thought to be predominantly paraffinic in nature, which is suggested for chemical use (*4*).

When we approach the range of solid paraffins we have even more difficulty in obtaining pure compounds. Paraffin wax, although largely paraffinic in nature, appears to consist of a mixture of many straight- and branched-chain isomers. The Fischer Tropsch process of making hydrocarbons by hydrogenation of carbon monoxide, used on a large scale in Germany, is said to yield a solid fraction, straight-chain in nature, which is being actively exploited by German chemists (*5*).

THERMAL CONVERSIONS

By the application of heat alone—with or without catalysts—it is possible to prepare many useful chemical compounds from the paraffins.

(*a*) *Manufacture of Hydrogen.*—Hydrogen is used in constantly increasing quantities for hardening fats, production of high-octane motor fuel, and the manufacture of methanol. It has been found that it may be obtained in the necessary large amounts from hydrogen-rich natural gas.

One process, now being used by a large oil company, manufactures hydrogen by subjecting natural gas to such high temperatures that it decomposes into elementary carbon and hydrogen (*6*).

$$CH_4 \xrightarrow{1100°C.} C + 2H_2$$

The gas is passed over brickwork maintained at 1100°C. where it is cracked into carbon and hydrogen to the extent of 70 per cent, the remainder being unchanged gas. The carbon is removed from the gas stream by water washing and by electrical precipitation; it finds extensive use in the rubber industry. The hydrogen, after suitable purification, is reacted by the usual catalytic-type process with nitrogen of the air to produce ammonia. Valuable by-products of the process are benzene, naphthalene, ethylene, and acetylene—each of which is produced in small quantity.

A second process (*7*) for making hydrogen from gas operates catalytically at 1000°C. utilizing the following reaction:

$$CH_4 + H_2O \longrightarrow CO + 3H_2$$

A second reaction is then conducted over a different catalyst at 500°C.:

$$CO + H_2O \longrightarrow CO_2 + H_2$$

The final exit gases consist of about 79 per cent hydrogen, the remainder being largely carbon dioxide.

(*b*) *Aromatic Hydrocarbons.*—Toluene and other aro-

matic hydrocarbons have wide uses as solvents, high-octane motor fuels, and as starting materials for making explosives (including TNT) and dyes. They are commonly obtained by distillation of coal tar, but in times of excessive demand other sources—normally uneconomic—have been tapped. In 1917 toluene was produced by high-temperature, low-pressure petroleum cracking. The yields were low, isolation was difficult, and the processes were abandoned as soon as the war pressure lessened. Since that time the search has continued for simple methods of converting paraffins to the relatively more useful aromatics.

When straight-chain paraffins of six or more carbons are passed at atmospheric pressure and a temperature of 450°–700°C. over a catalyst consisting of chromium oxide supported on activated alumina, aromatics are formed in quantitative yields, hydrogen being the other product (*8*).

$$CH_3(CH_2)_5CH_3 \longrightarrow C_6H_5CH_3 + 4H_2$$

This surprisingly clean-cut reaction is evidently a combination of ring formation and dehydrogenation. From normal hexane may be obtained benzene, and from normal heptane, toluene, as shown above. From normal octane is formed a mixture of ethyl benzene and the xylenes. The petroleum refiners have been studying this type of reaction intensively, since crude paraffin-rich naphthas can by this method be converted into high-aromatic products useful as high-octane gasoline and solvents.

Paraffins of less than six carbon atoms can be converted into mixtures of aromatics by the application of heat without a catalyst. For example, it has been found (*9*) that at 850°C. and atmospheric pressure mixed butanes (89 per cent normal, 11 per cent iso) can, by the use of a very short contact time, be converted to the extent of 16 per cent to volatile liquids. Of this 75 per cent was found to be benzene and 12 per cent toluene. At the same time appreciable quantities of styrene and butadiene were formed—both of which have recently attracted attention as constituents of resins and synthetic rubbers. Other paraffins may be similarly converted, although methane requires considerably higher temperatures than any of the other hydrocarbons.

(*c*) *Unsaturates.*—Unsaturated hydrocarbons such as isobutylene, butadiene, and acetylene are being used by chemical industry in constantly increasing quantities for the manufacture of solvents and synthetic rubbers. Many successful efforts have been made to produce these materials from the relatively useless paraffins.

Paraffins such as normal or isobutane may be converted in 90 to 95 per cent yields to the corresponding olefins (*10*) by passing them over a chromium-oxide activated-alumina catalyst at a temperature of 500° to 575°C. and approximately atmospheric pressure.

$$(CH_3)_2CHCH_3 \longrightarrow (CH_3)_2C{=}CH_2 + H_2$$

Apparently this type of dehydrogenation may be extended to others of the lower paraffins. Butene-1 may be further dehydrogenated to butadiene in good yields by the catalytic method.

$$CH_2{=}CHCH_2CH_3 \longrightarrow CH_2{=}CHCH{=}CH_2 + H_2$$

Non-catalytic thermal methods of dehydrogenation are widely used. Acetylene is produced in commercial quantities by exposing natural gas to the extreme conditions of the electric arc. It is produced as a by-product in many cracking processes (such as that discussed under hydrogen manufacture).

Ethylene is made (*11*) by cracking ethane-containing gases at 760°C., and at approximately atmospheric pressure.

$$CH_3CH_3 \longrightarrow CH_2{=}CH_2 + H_2$$

A valuable by-product of this process is butadiene.

ALKYLATION

A tertiary hydrogen is considerably more reactive than a primary or secondary hydrogen, and paraffins containing them will react with olefins to form new olefins:

$$(CH_3)_3CH + CH_2{=}CH_2 \longrightarrow (CH_3)_3CCH_2CH_3$$

This reaction takes place in the presence of alkylation catalysts such as sulfuric acid, or by the combined action of high temperature (505° to 510°C.) and high pressure (4500 lbs.) (*11, 12*). The above paraffin, referred to as "neohexane," has an octane number of 95 and is a useful component of aviation gasolines. It is being manufactured in quantity since the starting materials are cheaply available in large volume.

Alkylation is a general type of reaction. By reacting isobutane with isobutylene we obtain "isooctane"—another high-octane fuel for aviation use. Alkylation is hardly a textbook reaction, but it is finding increasing use in industry since it yields branched-chain paraffins which as a class have high octane numbers.

OXIDATION

Oxidation of paraffins has been studied for years, but difficulties in controlling the reaction and in separating the miscellany of products have discouraged practical application.

(*a*) *Carbon Black.*—Carbon black has long been manufactured by the oxidative dehydrogenation of natural gas using a restricted supply of air:

$$CH_4 + O_2 \longrightarrow C + 2H_2O$$

The yields of this process are low because a large portion of the carbon is oxidized beyond the elementary state. About one and one-half pounds of carbon are produced from 1000 cubic feet of gas for use principally in the rubber industry. It is stated that 18 pounds could be obtained from the same amount of gas by the use of more improved methods of production (*1*).

The exit gases from carbon black manufacture were found upon analysis to contain hydrogen and carbon monoxide. These are now being reacted catalytically to produce methanol:

$$CO + H_2 \longrightarrow CH_3OH$$

It has been stated that the exit gases also contain methanol and formaldehyde.

(*b*) *Formaldehyde and Methanol.*—During an attempt to remove small concentrations of oxygen from the air present as a contamination in natural gas it was found that its removal could be accomplished by heating the mixture over a catalyst (probably copper-copper oxide). The oxygen was converted largely to formaldehyde, together with some methanol and acetaldehyde (*13*).

These materials are removed from the gas and marketed. Chemists had been attempting for years to manufacture formaldehyde by direct methane oxidation and some success was achieved on a laboratory scale. But this process alone has achieved commercial success partly because (*a*) the reaction is conducted in such high dilution, and (*b*) part of the cost of the process may be carried under the heading of gas deaëration. Formaldehyde is used on a large scale for making synthetic resins.

(*c*) *Wax Acids.*—Liquid phase air oxidation of the higher paraffins is accomplished on a large scale today in Germany for the production of long-chain fatty acids suitable for making soaps and artificial fats (*14*). Air is bubbled through molten wax containing a dissolved metallic soap functioning as an oxidation catalyst. One type of wax used in this process consists primarily of long straight chains and is produced from carbon monoxide and hydrogen in the presence of a catalyst. During oxidation a wide variety of products is formed, including acids, alcohols, ketones, esters, and hydroxy acids. Breaking of the paraffin chains occurs to a considerable degree, leading to the formation of all molecular weight ranges of these compounds. If the oxidation is not stopped at the right point resinous materials are formed—perhaps by polymerization of the hydroxy acids. In any case, the production of an odorless and colorless type of soap from this type of oxidation mixture is a formidable problem, but apparently it has been solved on a large scale by German technologists.

HALOGENATION

The halogenation of the paraffins—limited in practice to chlorination—resembles oxidation in that the reaction is difficult to control and a mixture of products is obtained.

The only large scale chlorination of paraffins is that of the mixed pentanes derived from "casing-head" gasoline—the light gasoline obtained from natural gas by refrigeration or other processes. The pentane fraction, consisting largely of normal pentane and isopentane (2-methyl butane), is saturated with an inert diluent (hydrogen chloride produced previously in the reaction) and passed at a high rate of speed (about sixty miles an hour) through a reactor maintained at about 250° to 300°C. (*15*). Five isomeric amyl chlorides are formed which may be converted to an almost endless series of useful derivatives; for example, alcohols, amines, olefins, mercaptans, and nitriles. For the bulk of industrial purposes the mixture of halides is satisfactory, but if pure amyl derivatives are desired they may in many cases be obtained by simple fractionation.

NITRATION

Until about six years ago no one took seriously the idea of direct nitration of the lower paraffin hydrocarbons. At that time an investigator who may have doubted textbook statements regarding the lack of reactivity of the paraffins heated isobutane and nitric acid in a sealed tube. A mixture of nitroparaffins was obtained which could be separated by distillation.

Further research showed that all of the lower paraffins (except methane) could be nitrated in the vapor phase with the formation of a mixture of nitroparaffins (*16*). In practice the paraffins are bubbled through hot concentrated nitric acid and the mixture is conducted through a heated tube where the hydrocarbons react with the active nitrating agent, nitrogen peroxide, produced by decomposition of the nitric acid:

$$CH_3CH_3 \xrightarrow{HNO_3} CH_3CH_2NO_2 + CH_3NO_2 + H_2O$$

This relatively simple and smooth reaction has perhaps more than any other tended to dispel the old idea of the intractability of the paraffins.

The configuration $—CH_2NO_2$ present in the nitroparaffins is exceptionally reactive and provides a starting point for making a wide variety of useful compounds. The methylene group behaves in many ways like the same group in malonic ester, reacting with aldehydes, ketones, diazonium compounds, nitrous acid, and many other reagents. The nitro group is likewise capable of leading to many derivatives such as amines and oximes. The following table gives in outline a few of the many compounds which may be made from natural gas by way of the nitroparaffins.

Reagent	*Product*
Hydrogen	Amines
Aldehydes	Nitroalcohols
Ketones	Dinitroparaffins
Mineral acids	Carboxylic acids
	Hydroxylamine
Alkalies	Aldehydes
Halogens	Halogenitromethanes

When it is considered that no less than 20 chemical companies (*17*) are doing research in an effort to utilize natural gas as a chemical raw material, we may conclude that the future holds in store even greater developments in the realm of paraffin chemistry.

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AN IMPROVED APPARATUS FOR DEMONSTRATIONS WITH GASES

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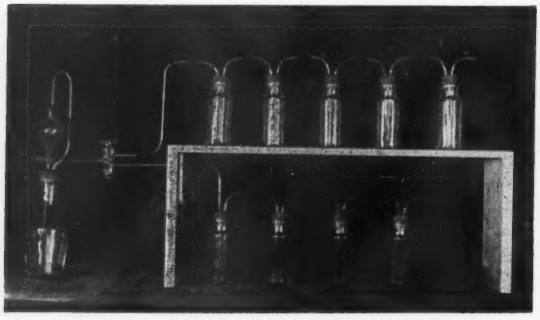
FOR schools with an inadequately ventilated lecture table and not enough hoods to enable a class to experiment with poisonous gases safely in the laboratory, the following apparatus will be of value. It can be used to show the preparation and properties of chlorine, hydrogen sulfide, sulfur dioxide, ammonia, oxides of nitrogen, and hydrochloric acid.



APPARATUS FOR DEMONSTRATIONS WITH GASES

The illustration shows a gas generating bottle fitted with a three-holed rubber stopper. A dropping funnel is used, and a glass tube connects the neck of the dropping funnel with the generating bottle to equalize the pressure. In this way back pressure, which may cause acid to splash out if it becomes sufficient to send bubbles of gas up the stem of the dropping funnel, is prevented. The third hole in the stopper carries the delivery tube which leads to a three-way glass stopcock. This enables the operator to send the gas through either of two trains of bottles. The bottles in the lower train should contain a solution of an appropriate absorbing agent while those on the top contain the chemicals which are to form a part of the demonstration. This device enables one to fill the demonstration bottles one at a time and then send the excess gas into the lower train so that each reaction can be observed and studied before the next begins. If it is necessary to remove bottles from the upper train it can be done without any appreciable amount of gas escaping.

A detailed description of the use of the apparatus for the demonstration of chlorine follows. Put 25–30 g. of potassium permanganate in the generating bottle and fill the dropping funnel with concentrated hydrochloric acid. Permanganate is superior to manganese dioxide because no heat is required, and the reaction practically stops as soon as the flow of acid is cut off. The lower train consists of two bottles which contain 10 g. of sodium sulfite in 50 ml. of water. Hypo may be used instead, but a precipitate of sulfur forms.

The bottles in the upper train are for the demonstration. The first contains water to remove hydrochloric acid carried over from the generator. The second contains concentrated sulfuric acid to dry the gas somewhat. In the demonstration of bleaching, the third contains dry colored cloth, litmus paper, and paper with spots of writing ink and India ink. In the next bottle are these same materials, moistened. The last bottle contains a solution of sulfite to absorb excess chlorine.

For the demonstration open the stopcock of the dropping funnel to allow the acid to drip slowly. Chlorine forms at once and is sent into the upper train. As soon as bleaching is shown, direct the gas into the lower train while the bottles used for bleaching are removed as a unit and taken to the hood. To show the action of chlorine with metals, non-metals, and compounds of hydrogen, insert three bottles in place of those removed. The first of these contains a sheet of thin copper foil. The second has an extra hole in the stopper; in this is a medicine dropper. The medicine dropper is filled with powdered arsenic or antimony, and the opening is closed by a thin layer of vaseline. In the third is a tuft of absorbent cotton moistened with turpentine. Pass chlorine through these bottles. The copper reacts with a bright flash. As soon as the next bottle is filled with gas, press the bulb of the medicine dropper quickly. As the powder sprays out it catches fire. When the gas comes in contact with the turpentine it forms white fumes of hydrochloric acid and the cotton soon becomes black. By directing the gas into the lower train after each reaction the experiments can be performed separately, so that there is ample time to study each before the next is begun.

The common experiments usually performed with the other gases named in this article can be adapted easily for use with this apparatus.

Fusion of Inorganic and Organic Chemistry in the General Course[1]

WILLIAM HERED

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IN RECENT years the emphasis in general chemistry has been transferred from the study of a mass of frequently irrelevant factual information to a consideration of the underlying principles of the science. This procedure has been justified on the ground that it is of more permanent value not only to the embryo chemist but also to the non-chemistry major.

During this time the presentation of the organic section of the general course has remained, on the other hand, largely a collection of isolated facts. A fundamental inconsistency exists in admitting the value of a deeper knowledge of chemistry and at the same time adhering to an out-moded manner of presenting the organic content.

Many of the principles of chemistry can better be developed through the use of illustrations taken from organic chemistry. Furthermore, the inclusion of concepts derived from organic chemistry serves to enrich the traditional material. These concepts may be so woven into the fabric of the general course that the usual sharp line of demarcation is obliterated.

It is the purpose of this paper to propose a fusion of organic, inorganic, and physical chemistry in such a way as to make of the first-year course a representative survey of chemistry as a whole. This course will then serve not only those who plan further courses in the subject, but also those whose contact with the science begins and ends with the general course.

The fact that chemistry is concerned with space and is not necessarily limited to two dimensions has not been emphasized sufficiently in the elementary course, and, accordingly, the average student finds the significance of structure and mechanism difficult to grasp in his advanced work. The space concept should be built up from the very beginning. Structure theory affords a convenient means. Too frequently, since inorganic compounds are used in illustration, structure theory stops with the molecular formula. Certainly we would not be satisfied with a description of a house in terms of the number of bricks or the area of glass surface contained in it; the sense of incompleteness left in the mind of the student is unfortunate and unnecessary.

The simpler organic compounds afford a basis for further elaboration of structure theory. The phenomenon of isomerism is not too difficult to grasp; the "picture" formula is a logical extension of the molecular formula. Fortunately the constancy of valence of elements in organic compounds and the prevalence of covalent bonds leads to a simplification rarely possible in the use of inorganic molecules as examples.

These covalent bond structures may be translated into their electron-pair equivalents after the electron theory has been presented. A discussion of the gradual development of polarity with the introduction of electron-attracting or electron-repelling atoms culminates in the development of the theory of ionization. Usually the ionic bond is introduced first, but the simpler covalent bond is a more logical starting point.

The free use of molecular models in connection with the structural formulas is suggested. The cry of "too much symbolism" is sure to be raised at this, but there is very little in what we teach that is not symbolic to some extent. Even the notions of mass and length are symbolic; they describe the results of experiment just as do "picture" formulas and models. There should be no objection to picturization if the limitations of such pictures are carefully indicated.

The concept of chemistry in space is amplified by a discussion of rate and mechanism of reaction. The dependence of rate on activation and on proper orientation lends itself admirably to treatment as a space phenomenon. For example, the "umbrella" mechanism for the substitution reaction

$$RBr + OH^- \rightleftharpoons ROH + Br^-$$

is simple enough for presentation and the accompanying idea of an intermediate reaction state is of considerable importance. A brief study of reaction mechanisms serves to moderate a too-excessive worship of the chemical equation. The fact that the equation is merely a record of the reactants and products of a reaction and gives no information as to the rate, mechanism, or formation of by-products is not to be ignored.

The nature of catalytic action in solution is poorly explained in many general courses. This is due, in part, to the scarcity of illustrative material available in inorganic chemistry. Organic chemistry, on the other hand, furnishes an abundant source of such material. The esterification reaction is a beautiful example of homogeneous catalysis and the role of hydrogen and hydroxide ions is not difficult to present by means of structural formulas.

Furthermore, by noting that the reverse reaction of the hydrolysis of esters is catalyzed by the same ions, one is led smoothly into the concept of systems in equilibrium and the absence of catalytic effects on such systems. Thus the usual material on gas-phase equilibrium is supplemented by a fine example of equilibrium in solution and the latter topic is given the importance it deserves.

[1] Presented before the Division of Chemical Education at the 101st meeting of the A. C. S., St. Louis, Missouri, April 9, 1941.

The study of the periodic system affords yet another opportunity to correlate the organic and the inorganic material. The tendency toward chain formation by elements such as lead, tin, silicon, and boron, which are neither strongly electronegative nor strongly electropositive, can be explained as a consequence of the type of bond exhibited in such chains. The culmination of this tendency in the compounds of carbon is a natural extension of this observation.

The stability of long carbon chains is contrasted with the marked instability of even short chains of the elements mentioned above. The importance of carbon to life can then be treated as a result of the infinite possibility of variation in the structure of carbon compounds and the consequent possibility of a high specificity.

The extreme complexity of proteins and high polymers extends this idea further and affords an opportunity to introduce a few of the modern physical methods of investigating structure. The use of the ultra-centrifuge, the X-ray, and electron diffraction illustrates the coöperation of the sciences in the search for truth.

The excursion into purely organic chemistry need not be long if the fusion has been effective. A brief mention may be made of typical homologous series as oxidation levels and of the meaning of the term oxidation-reduction as applied to the covalent bond. The work of the organic chemist in analyzing structures and in building molecules can be made an inspiring addition to this material.

The proposed reorganization of the course will make necessary an examination of the traditional material in the light of its actual value to the student. The "sacred cows" of chemical antiquity must be slaughtered if there is to be room for more valuable matter.

One such "sacred cow" is the balanced equation. Once the meaning of the law of conservation of mass has been transmitted, there is little further justification for the exhaustive and thorough development of methods of balancing complex equations of little importance.

Another "sacred cow" is the thorough development of the method of determining atomic weights. An understanding of the basis of the method is rarely acquired during the first year, and most students must resort to memorization of the operations involved. One solution is to defer an exhaustive discussion of this topic until later courses. In the same category are the topics of combining volumes, and of combination in simple and multiple proportions.

Detailed descriptions of industrial processes should also be curtailed. It is debatable whether a knowledge of scrubbing towers and filter presses constitutes part of a liberal education.

The degeneration of the general course at the end of the year into a wealth of unimportant detail concerning the properties of metals is likewise out of keeping with the purpose of the course. The hasty touch of qualitative analysis designed to fix these details in the mind of the student and to bribe him into attention by giving him a problem to solve has as much justification as a section in hemstitching for the arousal of feminine interest.

Finally there should be a judicious selection of the newer material. The principle of relevancy and not of recency should guide the selection. A course is not necessarily modern because the mesotron is mentioned.

In the summing up, general chemistry must present a coherent and unified picture of the methods used by the chemist, his reasoning, and the products of his reasoning, in such a manner that the student whose contact with chemistry is limited to one year may retain something of value to himself and to his own philosophy of life.

ALAS! THE DINOSAURS

"WHAT is a dinosaur, Daddy?" asks the five-year-old Head of the House.

"Well, 'dino' means 'terrible,' and 'sauros' means 'lizard,'" we tell him, stretching our mind until it creaks to recall the Greek words.

"What does he look like?"

"Oh, some were little fellows that weren't very dangerous but some grew to enormous size. If the largest were in our back yard he would stretch from the garage clear down to the apple trees, seventy feet away."

"Like a tremendous snake, Daddy?"

"No. He had a big fat body as high as this room. He had huge hind legs and very short front legs. He had a slinky neck longer than a giraffe's, with a tiny snake-like head and almost no brain at all. And he had an enormous tail."

"A scalesome, flailsome tail like the bi-colored python rock snake in the elephant story?"

"Very likely—a 'scalesome, flailsome tail' it must have been."

"I want to see him," says the incautious one.

"Oh, they are all dead now."

"Why?"

"Because they were too big for their own good, and too particular about how they wanted to live. Some of them would eat only certain kinds of vegetable matter; others ate nothing but meat. They were so big that they couldn't move around easily. In spite of their bulk they had no real weapons of defense. Their enemies could kill them without much trouble. And they hated change. They liked things as they were and when the world about them moved on, the dinosaur refused to accept new foods, new ways of living. Towards the end some of them tried, perhaps, but it was too late. So eventually they all died. We have a special word for beasts, and men, who show that kind of stubbornness. We say they are not 'adaptable.'"

—From *Silicate P's & Q's* of the Philadelphia Quartz Company

High-School Chemistry

The Chemistry Examination of the College Entrance Examination Board

THE September, 1940, issue of the JOURNAL OF CHEMICAL EDUCATION contained the chemistry syllabus proposed by the College Entrance Examination Board's Commission on Examinations in Physics and Chemistry, and suggestions and criticisms were invited. The membership of the Commission follows:

Dean John T. Tate, University of Minnesota (Chairman)
Doctor Otis E. Alley, High School, Winchester, Massachusetts
Dean Janet H. Clark, University of Rochester
Doctor Curtiss S. Hitchcock, Lawrenceville School, Lawrenceville, New Jersey
Mr. John C. Hogg, Phillips Exeter Academy, Exeter, New Hampshire
Professor Erwin B. Kelsey, Yale University
Mr. Alfred R. Lincoln, Technical High School, Springfield, Massachusetts
Professor Duane E. Roller, Hunter College
Professor Francis W. Sears, Massachusetts Institute of Technology
Professor Mary L. Sherrill, Mount Holyoke College
Mr. Howard A. Taber, Hotchkiss School, Lakeville, Connecticut

The suggestions received were given careful consideration and many have been incorporated in the following syllabus which has been adopted as the basis for the chemistry examinations to be set by the College Entrance Examination Board in 1942 and thereafter. Teachers will note, however, that the main topics remain unaltered. This syllabus will be of special interest to teachers whose pupils will take the Board's examination in chemistry in June, 1942.

REVISION OF CHEMISTRY REQUIREMENT—JUNE 16, 1941

The following suggested redefinition of the requirement in chemistry indicates the nature and extent of the *basic* preparation considered necessary for college work. It is estimated that from two-thirds to four-fifths of the school year will be required to cover the basic topics suggested in the minimum syllabus given in Part One and Part Two. Part Three is intended to show how the basic material of Parts One and Two can be amplified. Additional specific material designed to meet the needs of the community and adapted to the level of the student body should also serve to enrich the basic course. Questions on topics beyond this suggested area will not be included since it is felt that the science will be more effectively taught if the instructor is given greater latitude in the selection of topics.

The syllabus is divided into two sections:

(1) a minimum syllabus, Part One and Part Two;
(2) an extension syllabus, Part Three, which is subdivided into
  (*a*) commercial chemistry,
  (*b*) theoretical chemistry, and
  (*c*) organic chemistry.

Candidates will be examined on the minimum syllabus only. Quantitative problems may be set upon those topics marked with an asterisk (*).

In order that the objectives of the course of study may be fully realized, it is essential that the study of chemistry be accompanied by individual laboratory work as well as by class demonstrations. The laboratory work should occupy approximately one-third of the time devoted to chemistry and it should continue throughout the whole course. The need for accurate observation and the relation between observation and conclusion should be stressed. A list of experiments is not submitted as it is believed that the experiments will need to be varied according to the facilities of a particular institution. The arrangement of the syllabus does not imply a teaching sequence.

PART ONE—GENERAL CHEMISTRY

I. Chemical Changes.
  A. Element, compound, mixture.
    1. Chemical change versus physical change.
    2. Significance of terms—atom, molecule, radical.
    3. Types of chemical reactions.
    4. Electrochemical series of the common metals—limited to displacement reactions.
  B. Balancing of equations.
  *C. Quantitative relationship in chemical reactions.
    1. Significance of symbol, formula, equation, atomic and molecular weights.
    2. Laws of combining proportion:
      (*a*) Conservation of Mass.
      (*b*) Constant Proportions.
      (*c*) Multiple Proportions.
    3. Percentage composition.
    4. Problems based on chemical equations:
      (*a*) Weight relationships.
      (*b*) Volume relationships of gases.

5. Neutralization (quantitative).
   (*a*) Equivalent weights.
   (*b*) Molar solutions.
   (*c*) Normal solutions.

II. Physical Properties of Solids, Liquids, and Gases.
   A. 1. Kinetic molecular theory—relation between temperature and speed of molecules. Differences between solids, liquids, and gases from kinetic molecular viewpoint.
   2. Factors which influence rate of reaction (concentration, temperature, catalyst, and state of division).
   3. Equilibrium, mass action law, and principle of Le Chatelier as applied to gaseous reactions.
   *B. Gases.
   1. The temperature, pressure, and volume relations. Explanation in terms of the kinetic theory.
   2. Partial pressures of gases in a mixture—related only to the vapor pressure of water.
   3. Reduction to standard conditions (including vapor pressure of water).
   4. Avogadro's Principle.
   The relation of gram molecular volume, density, and molecular weight.

III. Periodic Law.
   Brief treatment giving variation in properties of the elements as illustrated in the halogen family and horizontally by argon through chlorine. Anomalies.

IV. Theory of Atomic Structure.
   A. Dalton's Atomic Theory.
   B. Modern atomic theory.
   1. Units of structure.
   Proton, neutron, electron, characterization as to mass and charge.
   2. Atomic number. Nuclear charge and arrangement of electrons (hydrogen through calcium).
   Isotopes (hydrogen, chlorine).
   3. Explanation of periodicity in properties of elements in terms of atomic structure.
   4. Ionic valence and its relationship to inert gas structure.
   5. Chemical combination explained in terms of atomic structure.
   (*a*) Electrovalence — combination and displacement; reactions in terms of electron transfer (oxidation and reduction).
   (*b*) Covalence—sharing of electrons in the formation of unionized molecules.

V. Electrolytes.
   A. 1. Physical evidence of dissociation in fused salts and bases and in water solution.
   2. Comparison of properties of electrolytes and non-electrolytes in water solution.
   B. Complete dissociation of salts and strong bases.
   C. Ionization.
   1. Ionization of acids by reaction with water.
   2. Degree of ionization of weak acids and weak bases—ionic equilibrium.
   3. Common ion effect as applied to weak electrolytes.
   D. Completion of ionic reactions by:
   1. Formation of a slightly ionized product.
   2. Formation of an insoluble gas or solid.
   E. Hydrolysis of salts (reaction of ions with water).
   F. Electrolysis of water solutions.

PART TWO—DESCRIPTIVE CHEMISTRY

In general, the study of any element should be developed in the following sequence: history, occurrence, preparation (most important laboratory and commercial methods), properties (physical and chemical), uses, and identification. Historical treatment should be limited to cases where it offers a sound teaching approach and where it is of particular significance in the study of an element; for example, as an introduction to oxygen and hydrogen.

Similarly, the study of the important compounds of the elements should include preparation, properties (physical and chemical), uses, and identification.

As illustrative of a typical study of an element and its important compounds, the topic *Nitrogen* is given in expanded form at the end of Part Two.

I. Chemistry of Some Non-Metals and Their Common Compounds.
   A. Oxygen.
   B. Hydrogen.
   C. Water.
   1. Composition by weight and volume.
   2. Purification (filtration and distillation).
   3. Chemical reactions:
   (*a*) With oxides—basis of classification of metals and non-metals.
   (*b*) With salts to form hydrates. Efflorescence.
   (*c*) Test for presence of water.
   4. Solutions:
   (*a*) Significance of terms—saturated, unsaturated.
   (*b*) Interpretation of solubility curves.
   D. Carbon (allotropes).
   1. Carbon dioxide and carbonic acid; types of carbonates; test for a carbonate.
   2. Carbon monoxide.
   E. Halogen family.
   1. Chlorine; hydrogen chloride and hydrochloric acid; hypochlorous acid.
   2. Bromine, iodine, fluorine, and the hydro-

gen compounds as compared with chlorine and hydrogen chloride.
3. Tests for chloride, bromide, and iodide ions.
4. Displacement reactions.

F. Sulfur.
1. Hydrogen sulfide, sulfides.
2. Sulfur dioxide—sulfurous acid, sulfites, bisulfites.
3. Sulfur trioxide (Contact process)—sulfuric acid, sulfates, bisulfates.
4. Tests for sulfide, sulfite, and sulfate ions.

G. The atmosphere.
1. Air as a mixture.
2. Nitrogen and the rare gases.

H. Nitrogen compounds.
1. Ammonia—test for ammonium ion.
2. Oxides of nitrogen—nitric oxide and nitrogen dioxide.
3. Nitric acid.
4. Test for a nitrate ion.

II. Chemistry of a Metal and Its Typical Compounds.

Sodium and its compounds.
1. Sodium hydroxide.
2. Sodium chloride.
3. Sodium carbonate and sodium bicarbonate (Solvay process).
4. Sodium nitrate.
5. Sodium hypochlorite.

III. Nitrogen (Outlined in expanded form for illustrative purposes).

A. History.
B. Occurrence.
C. Preparation.
1. Atmospheric nitrogen.
2. Pure nitrogen.

D. Properties.
1. Physical.
2. Chemical.

E. Uses.
F. Compounds.
1. Ammonia.
(*a*) Laboratory preparation.
(*b*) Commercial preparation.
(1) Synthetic (Haber).
(2) Cyanamid.
(3) Distillation of coal.
(*c*) Ammonium compounds.
(*d*) Test for ammonium ion.
2. Oxides of nitrogen.
(*a*) Nitric oxide.
(1) Preparation by:
(*a*) oxidation of ammonia (Ostwald),
(*b*) reduction of nitric acid.
(2) Identification.
(*b*) Nitrogen dioxide.
(1) Preparation by:
(*a*) oxidation of nitric oxide,
(*b*) reduction of nitric acid,
(*c*) heating of nitrates.
(2) Identification.
3. Nitric acid.
(*a*) Preparation.
(1) Laboratory.
(2) Commercial: oxidation of ammonia (Ostwald); from sodium nitrate.
(*b*) Properties.
(1) Physical.
(2) Chemical.
(*a*) Reaction of concentrated and dilute acid on:
(i) metals,
(ii) non-metals,
(iii) salts.
(*c*) Test for nitrate ion.
4. Uses of nitrogen compounds.

G. Nitrogen Cycle.

PART THREE—EXTENSIONS

Parts One and Two give the basic material for preparation for college work. It is recommended that the basic material be supplemented by topics from Part Three and also by various items of current and local interest.

I. Commercial Chemistry.
A. Chemistry of four metals and their common compounds: aluminum, iron, zinc, and copper.
1. Occurrence and extraction of these four elements from their ores.
2. Simple reactions of these elements and identification of their ions.

B. Fuels.
1. Coal gas, producer gas, water gas.
2. Acetylene.
3. Petroleum and natural gas; distillation and cracking process.

II. Theoretical Chemistry.
A. Distinction between a proton and the hydrated hydrogen ion (hydronium ion).
B. Laboratory determination of:
1. Equivalent weight.
2. Molecular weight.

III. Organic Chemistry.
A. Simple organic reactions.
B. Foods.
1. Components, carbohydrates, fats, proteins, vitamins.
2. Hydrolysis. Uses of starch and sugar.
3. Fermentation.

The Analysis of Gasoline in the High School

ISIDOR S. HIRSCHHORN *Madison High School, Madison, New Jersey*

INTRODUCTION

THE subject of gasoline chemistry is a vital concern of modern motor-minded youth. It is interesting, therefore, to investigate some of the characteristics of commercial gasolines and to provide a basis for grading them objectively. Although the interests of the consumer have been much stressed in recent years, few of the usual experiments in high-school or even college chemistry offer opportunities for a direct application to chemical products in everyday use. On the other hand, a thorough analysis of a commercial product is beyond the means of the average high-school laboratory. A determination of the boiling range of the hydrocarbons in gasoline is both simple and, fundamentally, a valid procedure of analysis. According to Ellis,[1] "the distillation test is of especial importance in the examination of motor fuels, because the boiling range of a gasoline and its content of volatile constituents have been shown to be intimately related to its general performance in an engine."

PROCEDURE

The method suggested in this paper does not yield results quantitatively equal to those of the American Society for Testing Materials or the Institution of Petroleum Technologists, but qualitatively they are closely comparable and useful as a basis for rating gasolines, if the limitations of the method are kept in mind.

The following procedure, adapted from the instructions of the Institution of Petroleum Technologists, is practicable for use in the high-school laboratory. A 250-ml. pyrex distillation flask with glass side arm is fitted to an ordinary glass Liebig condenser. A Centigrade thermometer (range −10° to 360°C.) is inserted through a rubber stopper in the mouth of the flask so that the bulb is at the same level as the side arm through which the vapors pass. This insures a reading of the actual temperatures of the vapors, and not of the liquid mixture boiling in the flask. One hundred ml. of the gasoline to be tested are introduced into the distillation flask, and then carefully heated. (Gasoline should never be poured from one vessel to another in the presence of flame or a heated electric coil.) The temperature at which the first drop of distillate falls from the condenser is recorded as the "initial boiling point." Then the volume of distillate is recorded at 10° intervals until decomposition of the residue begins. The latter is easily evident from the formation of brown fumes, and is due usually to the decomposition of the non-volatile dyes with which most commercial gasolines are colored. It is convenient to collect the distillate in a 100-ml. graduated cylinder.

When the residue has cooled, its volume is recorded as the "volume of residue." The temperature at which decomposition begins is the "endpoint." The difference between the total volume of distillate plus residue and the initial volume of 100 ml. is noted as "distillation loss," and is due to hydrocarbons whose boiling points are lower than the temperature reached in the condenser.

DATA

Table 1 shows typical results with several nationally advertised gasolines, as well as several known only locally. The refiner is designated by a number, the price by a letter—"A" for premium, "B" for regular, "C" for low-cost gasoline.

The data are most easily interpreted by graphic comparison. Figure 1, a typical graph derived from the data in Table 1, summarizes the results of the test on gasolines 1A, 1B, and 1C. Significant differences show in the very volatile fraction between 20° and 60°C., and in the fraction between 140° and 180°C. The former

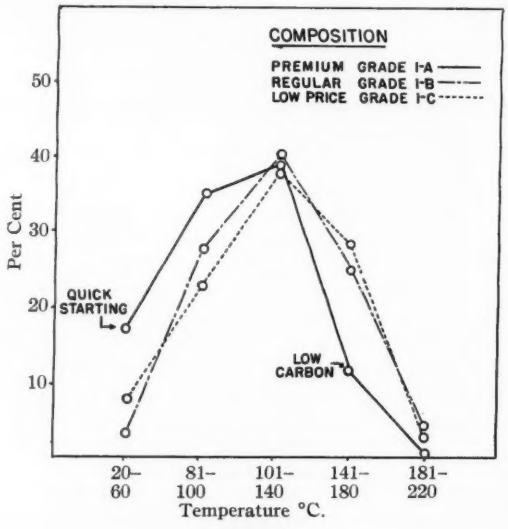


FIGURE 1

group is an important factor in starting an engine, while the latter contributes to incomplete combustion and carbon formation.

Table 2 grades the gasolines on the basis of the per cent of hydrocarbons with boiling points between 20° and 100°C. This range is chosen because it includes what is generally considered the volatile fraction in gasoline. The "distillation loss" is added to the recorded distillates, since it represents the most volatile hydrocarbons in the original sample. The premium gasolines all rate high on this scale, but several of the

[1] ELLIS, "The chemistry of petroleum derivatives," The Chemical Catalog Co., Inc., New York City, 1934, p. 1148.

TABLE 1

Brand	Initial B. P.	Ml. 50°	60°	70°	80°	90°	100°	110°	120°	130°	140°	150°	160°	170°	180°	190°	End-point	Ml. Residue	Ml. Distillation Loss
1A	40°	3	6	12	24	28	41	50	61	72	80	84	..	..	..	..	162	8	8
1B	40°	..	3	7	16	20	26	35	44	53	64	71	78	84	92	..	188	3	5
1C	45°	..	..	3	11	19	28	40	50	59	68	76	83	89	93	..	184	4	3
2A	50°	1	3	10	20	36	48	62	72	80	86	90	..	..	..	..	150	5	5
2B	45°	1	2	7	13	23	31	42	50	56	63	70	77	83	88	92	190	5	3
3A	40°	1	4	12	28	45	59	70	73	75	78	80	83	86	89	..	183	5	6
3B	40°	1	4	11	18	27	36	47	54	61	67	73	78	83	87	89	192	5	6
4C	40°	1	3	9	17	25	33	44	50	57	64	72	78	84	92	..	188	3	5
5B	37°	2	7	14	22	30	36	48	52	57	63	70	74	77	83	87	198	3	10
6C	45°	..	3	8	15	23	33	45	52	62	68	75	81	86	89	92	192	5	3

regular gasolines are near the bottom of the list. Thus gasoline 5B is better in this respect than either 2B or 1B, whereas 4C is the leader in its price class.

TABLE 2

PER CENT OF HYDROCARBONS, B. P. 20°–100°C.

Brand	Total Per Cent	Brand	Total Per Cent
3A	65	4C	38
2A	53	6C	36
1A	49	2B	34
5B	46	1B	31
3B	42	1C	31

Table 3 grades the gasolines on the basis of the per cent of hydrocarbons with boiling points between 20° and 60°C. The "distillation loss" has been added as above. Gasoline 5B surpasses all others on this scale, which represents the most volatile vapors, important in starting an automobile engine.

TABLE 3

PER CENT OF HYDROCARBONS, B. P. 20°–60°C.

Brand	Total Per Cent	Brand	Total Per Cent
5B	19	2A	9
1A	17	1B	8
3A	11	6C	6
3B	11	2B	6
4C	9	1C	3

In Table 4 the gasolines are graded according to the per cent of hydrocarbons with boiling points above 150°C. This includes the least volatile vapors, which are likely to be incompletely burned and carbon-forming. Gasoline 2A is best by far on this list, with 5B leading in its price class.

TABLE 4

PER CENT OF HYDROCARBONS, B. P. ABOVE 150°C.

Brand	Total Per Cent	Brand	Total Per Cent
2A	5	1C	21
1A	8	4C	22
3A	14	6C	22
5B	20	1B	24
3B	21	2B	27

SUMMARY

The experiment described in this paper is recommended for high-school use because it is simple to perform and yields useful objective information. The data show that by the distillation test the premium gasolines rate higher than the rest, but in some cases regular gasolines rate lower than the lower-priced ones. This of course has no relation to the "octane rating" most commonly used to characterize gasolines. In the course of these tests it was noted that the oil-soluble dyes employed in commercial gasolines are non-volatile, and hence would tend to accumulate and decompose in an engine. It is important to point out that, although a property of primary importance in gasolines is being measured, consideration must also be given to other factors such as color, presence of sulfur compounds, acidity, and octane rating. Seasonal tests are suggested because the composition of gasolines is varied to meet changing weather conditions.

The valuable outcomes of this experiment are: (1) experience for the student in a routine distillation procedure, (2) correlation between mathematics and chemistry in the accumulation of data and their graphic presentation, (3) development of critical scientific thinking in the interpretation of the conclusions, and (4) information of practical value to the consumer.

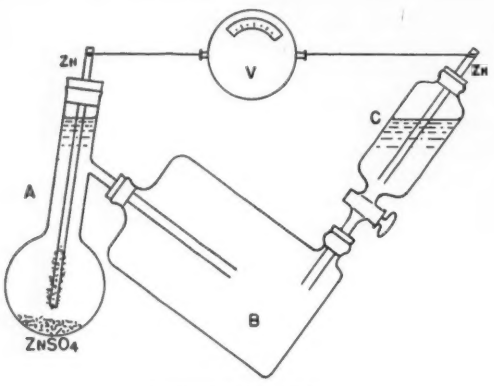
Courtesy of Warner Brothers Studio

CHEMICAL ICICLES

CHEMICAL icicles are one of chemistry's many contributions to the settings of Hollywood stages. The icicles are fashioned out of cellophane and silicate of soda—materials necessary to simulate the transparency of real icicles. After the icicles are shaped and before they are placed in position on the set, they are dipped in alcohol to make them rigid. As a final touch in producing a realistic effect, they are dipped in paraffin, which melts under the heat of the spotlights to create the illusion that the icicles are slowly melting. This method of simulating icicles was devised after a long period of experimentation with a variety of materials.

Out of the Editor's Basket

FROM the White Russian University at Minsk, U. S. S. R., comes a description of a new form of concentration cell by Emil W. Zmaczynski. The conventional demonstration, consisting of a tin rod running down through two layers of $SnCl_2$ solution of different density, has several drawbacks, not the least of which is the impossibility of showing the actual presence of electromotive force. The proposed new model is here



CONCENTRATION CELL

illustrated and requires a distilling flask (*A*), an aspirator bottle (*B*), and a separatory funnel (*C*), of suitable sizes. Dilute $ZnSO_4$ solution is introduced through the separatory funnel until it fills the aspirator bottle and overflows into the distilling flask. Crystals of $ZnSO_4$ are then introduced to saturate the solution in the flask. Long zinc rods are inserted and held in place by stoppers, as shown. An E.M.F. can be clearly shown on a galvanometer or millivoltmeter (*V*). When operated continuously for some time metallic crystals of Zn will appear on the rod in the flask. The operation of the cell may be interrupted by closing the stopcock of the separatory funnel.

● Stimulated by the present national emergency, the chemical industries are undergoing the most rapid expansion in history. This is reflected by the exceptional response of exhibitors at the 18th Exposition of Chemical Industries, to be held in Grand Central Palace, New York City, December 1 to 6, 1941.

Included among the exhibits will be many illustrating how, as defense production approaches full-blast operation, the chemical industries are bringing forward answers to problems which have never before been solved commercially.

More innovations will be made available through the new activities revealed at the forthcoming Exposition than at any time since it was founded in 1915, during the national emergency created by the last World War, according to Charles F. Roth, manager of these expositions.

● John B. Underwood of Grass Valley, California, High School suggests that the arc process of nitrogen fixation can be demonstrated to large audiences successfully by using an apparatus sandwiched between two sheets of window glass which are supported in a suitable frame. A large sheet of moistened litmus paper rests against the inside of the rear window glass. On the paper is a ring of copper wire, broken at several points where sparks are to jump. The wire is supported by slightly shorter pieces of glass tubing. The change in the color of the litmus paper becomes evident in a short while after sparking is begun when the experiment is performed in the limited amount of air held between the window panes.

(Has anyone a suggestion for demonstrating really modern nitrogen fixation, by the Haber process? All present demonstrations use the obsolete arc method.)

● More than 160 of the nation's leading scientists and scholars, including thirty-two distinguished men and women who will be awarded honorary degrees, will report basic achievements and advances in learning in a five-day series of symposia sponsored by the University of Chicago. The learned gatherings will be held on the Midway Quadrangles in the week climaxing the celebration of the University's Fiftieth Anniversary, beginning September 22.

Thirty-nine universities, including six in foreign nations, and fifteen museums, research organizations, and government agencies will be represented in the symposia. They will deal with newest fundamental advances in the biological, physical, and social sciences, the humanities, law, business, religion, and social service, in keeping with the theme of the University's celebration, "New Frontiers in Education and Research."

Sessions in the biological and physical sciences will be held jointly with the American Association for the Advancement of Science.

Symposia subjects include: aviation medicine, cancer of the lungs, the problem of overabundant evidence in historical research, cosmic rays, oil geology, social implications of vitamins, transformation in atomic nuclei, and the relations of government, the individual, and large scale enterprise in the economy of the future.

● Some of our readers may be interested in a pamphlet recently issued by Dun and Bradstreet (290 Broadway, New York City), entitled "The War of Metals." It is a discussion of metal shortage and the application of priorities as they affect manufacturing, distribution, and civilian use. Some interesting data are contained, referring to the normal uses of several of the common metals—aluminum, copper, nickel, zinc, tin, and lead—as well as examples of various substitutions which are being made.

● M. L. Marshall of Texas State College for Women says the following is a good way to loosen a rubber stopper that has been "frozen" to glass tubing: Wet thoroughly and roll it on the floor under your foot!

● "Audible publishing" has made its advent in the publication field. At least one organization (Recorded Lectures, Inc.) is "publishing" short talks by authorities in various fields, on phonograph records for class use. The list of those available is rapidly increasing. There are attractive possibilities in this, which can be left to the imagination.

● The U. S. Commissioner of Education has made an urgent appeal to American schools to aid the total defense of this hemisphere by "prompt enlargement" of study of Latin American countries. "Adequate defense must be hemispheric, and it must be total—immediate and long-range—military, economic, and educational."

We, too, have long been anxious to increase our contacts for the JOURNAL in South America. We would be glad to receive from our readers suggestions as to possible subscribers and contributors in the South American countries, as well as items in the field of chemical education which would be of mutual interest to readers in both continents.

● The government-supported program of special training which has been going on for the last year at more than a hundred colleges and universities, designated as Engineering Defense Training, has been extended for the next year to include the fields of chemistry, physics, and production management. Seventeen million dollars has been appropriated for the enlarged work in Engineering, Science, and Management Defense Training, five hundred thousand of which is specially allocated to collegiate-grade courses in chemistry, part-time or full-time, which will presumably be planned and offered by institutions throughout the country. The great majority of the work done in the emergency training program consists of "in service" courses, given part-time for men who are already employed and who wish to increase their productive capacity by further training. There is no intention that these courses shall supplant or dislocate the regular training of professional engineers, chemists, or physicists.

PRELIMINARY REPORT ON THE CONFERENCE OF THE COMMITTEE ON EXAMINATIONS AND TESTS

DURING the week of July 21–26, the Committee on Examinations and Tests held a conference at the University of Chicago to reformulate the objectives of the General Chemistry Examination which is issued yearly by the Coöperative Test Service. Besides the eight members of the committee, twelve other members of the Division of Chemical Education participated. During the first two days the attention of the group was focused upon the objectives of courses in general chemistry and the technics which may be used to measure the student's progress. The discussion was led by several authorities on test construction attached to the Board of Examinations of the University of Chicago: Dr. Ralph W. Tyler, Chairman of the Department of Education and Chief Examiner; Dr. Louis P. Heil, Associate Professor of Education and Examiner; Dr. Robert J. Havighurst, former director of the General Education Board; and Dr. T. A. Ashford, Instructor in Chemistry and Examiner. In addition, the group had the benefit of the experience of Dr. Alexander Calandra of Brooklyn College with the Coöperative Test Service, and of the members of the committee who have supervised the construction of the earlier forms of the Coöperative Chemistry Test; namely, Professor B. Clifford Hendricks, of the University of Nebraska, and Professor Otto M. Smith, of the Oklahoma Agricultural and Mechanical College.

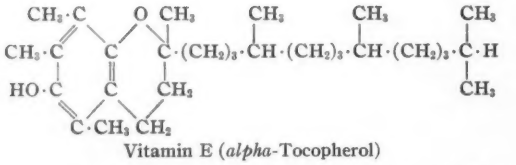
The remainder of the conference was devoted to a discussion of the 1941 Form of the Coöperative Chemistry Test; to the construction of test items for the 1942 Form; and to the formulation of plans for the committee for the next two years. In the experimental form, the 1942 Test will carry sections designed to measure attainment in the following objectives: *Information*, knowledge of facts, definitions, and properties of the elements and their compounds; *Application of Principles*, use of chemical principles to solve numerical problems, balance equations, and predict the results of chemical reactions; *Understanding of Theories*, relationship and distinction between evidence and theory and the interpretation of phenomena in terms of theory; *Laboratory Training*, some skills to be expected as a result of organized laboratory work. Throughout the examination an effort will be made to determine the extent to which students are aware of the impact of chemistry upon their physical and social environment, and the relationship of chemistry to industry, politics, and public and personal health. Instead of devoting a separate section to this objective, items bearing upon social implications will be included in each part of the test. The experimental form of the new test will be given in colleges and universities which offer one-semester courses in general chemistry. After the difficulty and validity of each item have been determined, *Form 1942* will be constructed. Teachers who wish to participate in the preparation of the 1942 test are requested to communicate with the chairman of the committee, Professor O. M. Smith, Oklahoma Agricultural and Mechanical College, Stillwater, Oklahoma.

In addition to the construction of tests, the committee plans to prepare a "Manual on Examinations" for the instruction of teachers in the methods of test construction and the many uses to which a validated objective examination may be put. The committee is considering the possibility of setting up a bureau where test items, pertaining to the field of general chemistry, may be collected for the use of teachers. The advantages of the use of separate answer sheets are not well understood by the majority of chemistry teachers, although their use is gradually increasing, and it has been decided to publicize this feature of the testing program more widely. In this connection, a list of stations where these answer sheets may be scored electrically is being compiled. Information concerning the possibility of establishing such stations in various parts of the United States will be welcomed.

The committee is grateful to the University of Chicago for the excellent accommodations and the hospitality afforded them. The conference was so successful that plans are already under way to hold another in September, 1942.

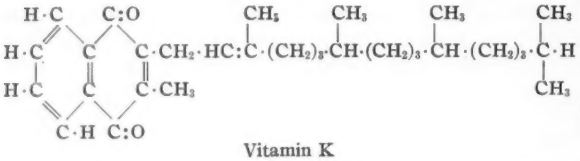
What's Been Going On

(*Continued from page 402.*)



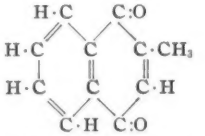
Vitamin E (*alpha*-Tocopherol)

Vitamin E is the antisterility factor. It is a yellow oil, which was originally obtained from the germ of wheat, but is now produced synthetically. It is reported to be essential in human nutrition for normal placental functioning in the female, and for normal germ-cell formation in the male.



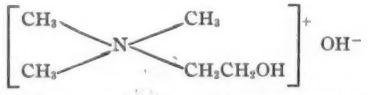
Vitamin K

Vitamin K is the anti-hemorrhage factor. One of the essential factors for blood clotting is prothrombin, a deficiency of which results in hemorrhage. Vitamin K in some way protects against this deficiency or serves as a substitute.



2-Methyl-1,4-naphthoquinone (Vitamin K Substitute)

2-Methyl-1,4-naphthoquinone, on a weight basis, possesses about three times the activity of vitamin K as an anti-hemorrhage agent. It is produced synthetically.



Choline, Hydroxyethyltrimethylammonium hydroxide

Choline is essential for growth, lactation, normal fat metabolism, and certain structural elements in body tissues. Experiments have indicated that the presence of choline in the diet prevents *perosis* in turkeys and the condition known as fatty livers. Its deficiency results in impairment of the functions of the liver and kidney and the methylation processes, as well as a hemorrhagic degeneration of the kidneys, enlargement of the spleen, and regression of the thymus.

Other vitamins that have been recognized but whose structures have not been established and whose functions are none too well defined are described by H. J. Heinz Company in their Nutritional Charts as follows:

"Vitamin A_2—A fat-soluble factor with activity equal to vitamin A_1 which is found in the pigment epithelium of the eye and in the livers of fresh water fish, and characterized by specific absorption bands different from vitamin A_1.

"Vitamin B_4—A water-soluble, thermo- and alkali-labile, growth-promoting factor essential for rats and chicks and found in yeast and liver. This vitamin is believed to be concerned in the paralysis of rats and chicks.

"Vitamin F—No recognized standing among nutrition authorities. This term has been mistakenly used to designate certain essential fatty acids required by rats.

"Factor U—A water-soluble, growth-promoting factor found in yeast, middlings, wheat bran, and alfalfa, thought to be essential for chicks.

"Factor W—A thermolabile, water-soluble factor in liver extract essential for growth in rats, chicks, and dogs.

"Factor Y—A thermostable, water-soluble factor found in autoclaved yeast, green vegetables, egg yolk, and beef liver, which is thought to be concerned with dermatitis in rats. Probably related to or identical with vitamin B_6.

"Eluate Factor—A water-soluble, thermostable factor found in pork liver which can be prepared as an eluate in the making of the filtrate factor. Prevents dermatitis in rats and probably is related to or identical with vitamin B_6.

"Anti-gizzard erosion factor—A factor found in kale, wheat bran, and middlings, liver, kidney, and lung tissue, which prevents erosions in the lining of chick gizzards, presumably owing to a lack of bile which contains cholic acid. Chondroitin sulfuric acid appears to have the property of acting as a preventive of the gizzard lesions. The factor is not necessary for growth.

"Grass juice factor—A growth-promoting, water-soluble factor found in summer milk and green grass which is essential for rats and guinea pigs. It is destroyed by autoclaving.

"Anti-achromotrichia factor (anti-gray hair factor)—A water-soluble factor found in yeast, liver, rice bran, molasses, and alfalfa. It is thought to be essential for the maintenance of a normal black color in the fur of rats, silver foxes, dogs, and guinea pigs; related in part to riboflavin and pantothenic acid deficiencies.

"Egg-white factor (vitamin H)—A factor found in yeast, liver, kidney, and milk, which prevents dermatitis produced in rats when they eat raw egg white. It is identical with biotin, a yeast growth factor, and co-enzyme R."

The requirements of the more important vitamins according to "Nutritional Charts" are as follows:

VITAMIN REQUIREMENTS

	*Requirement in International Units**				
Definition of a Unit	*Infants*	*Children*	*Pregnant or Lactating Women*	*Adults*	*Substance Supplying Adult Requirement*
Requirement, per body weight of	10 kg.	20 kg.			
A—I. U. = 0.6 μg.† beta carotene	3000	4500	9000	4000	5 g. cod-liver oil
B—I. U. = 3 μg. thiamin hydrochloride	100	200	800	400	9 g. dried yeast
C—I. U. = 0.05 mg. ascorbic acid	800	1500	2000	1000	100 cc. orange juice
D—I. U. = 0.025 μg. calciferol	750	750	1000	500	6 g. U.S.P. cod-liver oil
E (No definite evidence of human requirement)	....	....	....	....	...
G—Sherman unit = 2.5 μg. riboflavin	320	400	1200	600	30 g. dried yeast
Nicotinic acid	....	....	50 mg.	25 mg.	1/2 lb. meat

* Human requirements cannot be stated with the same accuracy as animal requirements.

† Microgram (μg.) = 1 millionth of a gram.

—ED. F. DEGERING

RECENT BOOKS

TEXTBOOK OF CHEMISTRY. *A. L. Elder*, Professor of Chemistry, Syracuse University. First Edition. Harper and Brothers, Publishers, New York City and London, 1941. viii + 751 pp. 270 figs. 15 × 23.5 cm. $3.75.

This text is written for students who expect to make some branch of science their life work. Interest in science and a fundamentally sound but not extensive background in mathematics are presupposed, but previous courses in chemistry are not necessary. The text is divided into thirty-nine chapters which vary in length from three to sixty-seven pages. The first eighty-three pages contain seven chapters, with the titles: State of Matter; The Composition of Matter; Methods Used in the Discovery of the Elements; Composition of Crystals, Molecules, and Atoms; Arrangement of the Fundamental Units of Matter in the Atoms; The Nucleus of the Atom; Crystal Structure; and the Arrangement of Atoms in Molecules. This part of the text includes: Periodic Table, isotopes, valence, the determination of molecular and atomic weights, radioactivity, and transmutation of the elements. Pages 84 to 335 are devoted to general principles of chemistry under such headings as: Types of Chemical Reaction; Nomenclature; Properties of Gases, of Liquids, of Solids, and of Ions; Solutions; Electricity as a Tool; Chemical Equilibrium; Colloids; The Atmosphere; and Water. Three chapters entitled: Hydrogen, Oxygen, and Water are the only ones up to page 336 whose names suggest particular chemical substances. The last four hundred pages of the book are devoted to the sources, preparations, properties, and uses of the elements and their compounds.

The discussions include considerable history, and a list of references is found at the close of each chapter, followed by a set of questions which will indicate to a student, if he uses them, the extent of his mastery of the chapter. The presentation of theory first permits theoretical discussions of all of the preparations and uses of substances. While many obsolete methods are described the modern processes are also presented and the distinction between old methods which illustrate chemical principles and modern methods which are commercially feasible is clearly made. All of the ideas usually presented in elementary texts are included. The grouping is not that of the classical text, but the author prepares for each idea before it is introduced.

The discussion of the arrangement of electrons in "energy levels" within the atom, and its bearing upon valence and oxidation number, leaves something to be desired. But on the whole, the author has accomplished his purpose. Qualified students will receive a systematic, integrated view of the structure of matter, its characteristic properties and reactions, and how these structures and reactions produce interesting phenomena and commercial products. Those desiring an easy, superficial course should not attempt to use this text.

F. E. BROWN

IOWA STATE COLLEGE
AMES, IOWA

CHEMICAL WARFARE. *C. Wachtel*, Founder, Pharmacological Section of Kaiser Wilhelm Institute; Founder and Former Director, Institute of Industrial Hygiene and Professional Diseases. Chemical Publishing Co., Inc., Brooklyn, N. Y., 1941. ix + 312 pp. 13.5 × 21.5 cm. $4.00.

This book gives a fairly detailed account of the development of chemical warfare. The modern aspects of this historical picture deal particularly with German progress during the first World War, the author having been called by Professor Fritz Haber to organize the pharmacological research division of the Institute. The accounts of Allied progress and of technological advance in the manufacture of poison gases and of defensive protection are, therefore, relatively meager.

The author develops, in broad terms, the need for and the effect of different types of war gases, together with the technic of subjecting the enemy to them. He stresses the need of organized planning for the development of new gases and protective measures against new and old gases. He sets up, in detailed outline, the subdivisions of an organization, both in research and in manufacture, which would be necessary for an efficient functioning of the chemical warfare service, offensively and defensively. In the later chapters of the book he discusses in detail the physiological and chemical properties of every war gas that has been used or proposed. The tactical use, the effects, detection, and the treatment are described for each gas. No mention is made of the methods of manufacture.

The author is deeply interested in the philosophy and economics of gas warfare. He waxes eloquent, at times, in his admiration for his former chief, Professor Fritz Haber, who seems to have been the guiding hand of German chemical warfare. The viewpoints of the author are essentially German, though the author is now *persona non grata* in Germany. Occasional Teutonic complexities of sentence structure make reading a little difficult.

The best portion of the book is the strictly scientific description of war gases. Because of the completeness of this information, the book will prove valuable both to the scientist and to the layman.

W. A. FELSING

UNIVERSITY OF TEXAS
AUSTIN, TEXAS

PRACTICE OF ORGANIC CHEMISTRY. *H. Adkins, S. M. McElvain,* and *M. W. Klein*, University of Wisconsin. Third Edition. McGraw-Hill Book Company, Inc., New York City, 1940. ix + 294 pp. 22 figs. 13.5 × 20.5 cm. $2.50.

This third edition of the well-known laboratory textbook of Adkins and McElvain has been revised with the aid of Professor Klein. In some respects, the arrangement of subject matter differs from the majority of similar books now on the market. An introductory chapter (10 pages) includes general directions for working in the laboratory; a second section of 99 pages, entitled "Certain Important Experiments," contains directions for qualitative analysis, the determination of physical properties, the purification of substances, and the preparation of about 50 typical organic compounds. A few experiments are devoted to class reactions, and the section terminates with a paragraph on library work ("Literature Preparation").

Other chapters in the book are entitled: Purification of Organic Compounds, Routine Laboratory Operations, Oxidation, Reduction, Halogenation, Alkylation, Arylation and Esterification, Dehydration, Hydration, Hydrolysis, Alcoholysis and Ammonolysis, Nitration and Sulfonation, The Diazo Reaction, The Friedel-Crafts Reaction, Intramolecular Rearrangements, and a miscellaneous chapter entitled, Other Important Reactions.

It seems to the reviewer that the section on general organic reactions is an especially desirable feature, since this information is otherwise available to the student only through such reference works as "Houbens Methoden." The directions are clearly and satisfactorily written and in such a manner that the student can readily follow them. Errors in the text are minor in character and very few in number.

F. W. BERGSTROM

STANFORD UNIVERSITY
STANFORD UNIVERSITY, CALIFORNIA

AIDS TO INORGANIC CHEMISTRY. *R. G. Austin*. The Williams and Wilkins Company, Baltimore, Md., 1940. x + 348 pp. 9.5 × 16 cm. $1.50.

This small volume does not pretend to be a complete textbook of the subject, being intended primarily for use by students who have already attended lectures on inorganic chemistry. It is more for ready reference, its compact form and orthodox arrangement of material facilitating its use in this capacity. There has been some attempt to stress the physiological action of common inorganic substances to make the work interesting and useful to students of medical and allied sciences.

MODERN PRACTICE IN LEATHER MANUFACTURE. *J. A. Wilson*, Sc.D., Consulting Chemist to the Leather Industries. First Edition. Reinhold Publishing Corp., New York City, 1941. xxxiii + 711 pp. 460 figs. 15 × 23 cm. $9.50.

The publication of a new book on leather is something of an event. Consequently, one approaches MODERN PRACTICE IN LEATHER MANUFACTURE with pleasant anticipation. The author's purpose is to give to tanners "all the details of operation involved in making each of the many different types of leather and the fundamental principles underlying each operation," and "to pause and portray the new and higher level reached by the industry . . . ."

Few men in the leather field have the technical qualifications, the knowledge of the industry, and the ability to accumulate and organize the wealth of material which the author presents in this volume. He has drawn not only on his own experience but has procured information from an imposing list of contributors. While it is so comprehensive that it cannot be authoritative on all phases of the tanning industry, it is infinitely superior to any of the "cookbook" types which have been so commonly written about leather. As a reference book and with its excellent index and wealth of references it will find a definite and important place in tannery practice.

From a standpoint of chemical education, MODERN PRACTICE IN LEATHER MANUFACTURE should prove of value when details of operating procedure or equipment are in question. The wealth of illustrations, photomicrographs, diagrams, and data cover most of the points about which a student might have questions. This book should prove a welcome addition to school reference libraries.

KENNETH E. BELL

A. C. LAWRENCE LEATHER COMPANY
PEABODY, MASSACHUSETTS

FLUORESCENT LIGHT AND ITS APPLICATIONS. *H. C. Dake*, Editor, *The Mineralogist Magazine*, Co-author, "Quartz Family Minerals," Honorary President, Northwest Federation of Mineral Societies, and *J. DeMent*, Associate Editor, *The Mineralogist Magazine*, Research Chemist, The Mineralogist Laboratories. First Edition. Chemical Publishing Co., Inc., Brooklyn, N. Y., 1941. xiii + 256 pp. 25 figs. 15 × 23 cm. $3.00.

In writing this book, the authors have undertaken the rather ambitious project of discussing all phases of luminescence which might be of practical interest and importance to readers of all degrees and types of training. As a result, most readers will find only a portion of the book useful. Its wide scope naturally leads to a superficial treatment of many of the specific phases considered. Nevertheless, students of luminescence, particularly those interested in mineralogy, will find FLUORESCENT LIGHT AND ITS APPLICATIONS of use as an introduction, both because of its elementary treatment of many aspects of the subject and because of its lengthy bibliography.

Unfortunately, the reader will find many errors and omissions in the text. He may also find the type used in some of the mathematical equations rather puzzling.

J. WILLIAM ZABOR

WILLIAMS COLLEGE
WILLIAMSTOWN, MASSACHUSETTS

ANALYTICAL RECORDS FOR QUANTITATIVE CHEMICAL ANALYSIS. *M. G. Mellon*, Ph.D., Sc.D., Professor of Analytical Chemistry, Purdue University. Edwards Brothers, Ann Arbor, Mich., 1941. 25 + 176 pp. 15 × 23 cm. $0.60.

This book represents the essence of the author's experience with the problem of keeping laboratory records that will meet the requirements of patent and other legal cases. Although the notebook is primarily a blank book for the recording of data, it presents briefly the main points involved in keeping such records, together with a number of typical examples. A small logarithm table and the 1941 atomic weights provide for the necessary calculations. The notebook should prove particularly helpful to students.

ORGANIC CHEMISTRY. AN INTRODUCTION TO THE CARBON COMPOUNDS. *N. D. Cheronis*, Professor of Chemistry, Chicago City Colleges. Thomas Y. Crowell Company, New York City, 1941. xv + 728 pp. 44 figs. 115 tables. 15 × 23 cm. $4.00.

The arrangement of subject matter in this text departs from the usual order of presentation. One of the most notable deviations from general practice is the somewhat intensive treatment of the hydrocarbons in the early chapters and an introduction to the study of benzene in Chapter 9 in connection with cyclic unsaturated hydrocarbons. The usual separation into aliphatic and aromatic compounds is not made.

In the preface attention is called to the difficulties encountered by the beginner in organic chemistry and to the confusion which too frequently results. The purpose of the present change in order as expressed by the author is "to provide a clearer and more logical method of approach."

An interesting and worth-while innovation is a brief statement in the table of contents of the "objective" of each chapter. The objective of the first chapter is: "To project the study of organic chemistry against a background with which the student is assumed to be familiar; namely, inorganic chemistry." In general the first four chapters provide an orientation and survey of the field to be studied.

Although the study of benzene is introduced quite early for the purpose of aiding in the "acquisition of a unified knowledge," the discussion of the more complex aromatic compounds is postponed to the latter part of the text.

A clear introduction to electronic formulas is given in Chapter 4 which deals with the structure of atoms and molecules. A judicious use of electronic formulas is also made in subsequent chapters whenever the author believes they are necessary to give a better picture of relationships.

Following Chapter 13 on the amines there are two chapters on the theories of organic chemistry. In these chapters the more elementary theories of organic chemistry are reviewed and expanded and correlated with factual material which has already been given. In Chapter 39 on physiologically active compounds there is presented an integrated discussion of alkaloids, vitamins, sterols, hormones, and synthetic drugs. The last chapter, on synthetic polymers, gives an elementary introduction to the synthesis of polymers and their applications including a brief description of the most important commercial synthetic resins, rubbers, and fibers.

In general the subject matter of the forty-one chapters has been carefully selected and well organized. The treatment is modern and up to date. Controversial subjects are neither ignored nor discussed in too great detail. The style is clear and should be easily followed by the student. The typography, paper, and binding are attractive. A liberal use of equations, structural formulas, and tables adds to the value of the book. Teachers of organic chemistry should give this text careful consideration.

GEORGE H. COLEMAN

STATE UNIVERSITY OF IOWA
IOWA CITY, IOWA

CHEMISTRY FOR PHOTOGRAPHERS. *A. R. Greenleaf*. American Photographic Publishing Co., Boston, 1941. xi + 177 pp. 13.5 × 19.7 cm. 1 fig. $2.00.

This book contains chemical information required by the photographer for an intelligent understanding of his work, without being an exhaustive treatise on the subject. It is simply presented, with definitions of chemical terms in the first chapter of the book. The next fourteen chapters deal with the various chemical processes involved in photography, followed by a chapter outlining darkroom procedures and giving a list of the necessary minimum equipment. Chapter 17 gives weights and measures, with simple factors for the interconversion of formulas expressed in the different systems. The formulary at the end contains representative recipes for the guidance of the amateur who wishes to make up his own solutions. The book is designed to provide a sounder basis for successful work in photography.

New Reinhold Books

PHOTOCHEMISTRY OF GASES

by

WILLIAM ALBERT NOYES, JR.

Professor of Chemistry, University of Rochester

PHILIP ALBERT LEIGHTON

Professor of Chemistry, Stanford University

The science of photochemistry is constantly growing in importance as a means of extending our knowledge of the behavior of molecules. Standing as it does midway between chemistry and physics, an understanding of its fundamental principles and applications is essential for all those engaged in research in these two vast fields. Much progress has been made, both experimentally and theoretically, in the past ten years, and there now exists an appreciation of the type of data which should be obtained.

The authors present this monograph as a review of that portion of photochemistry dealing with reactions in the gas phase. Some of the chapters have been written with a view to *teaching* the subject matter in colleges; others constitute *critical discussions* of typical reactions. The volume includes a comprehensive survey of photochemical data, and a detailed bibliography, which will greatly aid research workers in looking up data on a given reaction. It is thus a combined textbook and source book, covering all that is fundamental in this field.

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A list of Ring Systems used in Organic Chemistry

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Research Laboratories, Universal Oil Products Company

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REINHOLD PUBLISHING CORPORATION, 330 W. 42 St., New York, N. Y.

TRADE ANNOUNCEMENTS

Portable Twin-Unit Digestion Rack

The Precision Scientific Company, 1750 North Springfield Avenue, Chicago, Illinois, announces the development of a new portable Twin-Unit Kjeldahl Digestion Rack, suitable not only for Kjeldahl digestions, but for other procedures in which fumes are generated. Being entirely self-contained, the unit does not require a fume hood. The assembly consists of a pair of 550-watt electric heaters in a Stainless steel case, with individual switch control and wiring according to National Electrical Code; Tellurium lead fume exhaust manifold, with individual hood for each flask of same design as used on larger Kjeldahl equipment. The manifold does not employ protruding nipples. Equal "pull" is exerted at each hood by a pair of suction orifices, one directly opposite the flask mouth and the other at the lowest portion of the hood to assist suction and to convey condensate from the hood into the manifold. Suction is exerted by a Stainless steel aspirator. Fumes are drawn into the stream of water flowing through the aspirator and carried off through any convenient drain. Electric heater refractories are reversible, and the apparatus is adjustable, to take 500 or 800-ml. flasks.

Washing Machine for Laboratory Glassware

A washing machine for washing of laboratory glassware, known as the "Charlab" has been introduced by *Eimer and Amend, New York City.* It is claimed that in addition to washing, complete sterilization may also be obtained. The unit is said to be built on a new washing principle. Heretofore, it is said, most mechanical washing has been accomplished by totally submerging the articles to be washed and then agitating the water, or by spraying. In the Charlab machine revolving disks are used, which are arranged to support a varied arrangement of adjustable trays or baskets. These carry the glassware into the washing solution and out again to drain. The continual filling and draining is said to give a high degree of cleaning, removing salt deposits, precipitates, wax pencil marks, etc.

After the glassware has been washed the washing solution is drained and a hot or cold water rinse may be applied. If the glassware is to be sterilized, steam is turned on. The Charlab Junior machine is said to accommodate any type of glassware not over 12″ x 12″ x 8″ and a larger model, sizes exceeding this. With small items such as test tubes, microscope slides, and petri dishes, accessories have been designed to act as holders. Larger items such as funnels, flasks, and bottles need no special accessories and are held in place by adjustable screens and keeper rods.

Further information may be obtained by writing *Eimer and Amend, New York City.*

A New Free Handbook on Swimming-Pool Sanitation

A comprehensive treatise said to cover every phase of swimming-pool sanitation has just been published by the *Mathieson Alkali Works, Inc., 60 East 42nd Street, New York City.*

This 50-page book, entitled "Keeping the Pool Safe and Sanitary," discusses modern methods of purifying the water of swimming pools, from the small private pools to large natural bodies of water. It also gives directions for algae control, prevention of the spread of athlete's foot and other infectious diseases, control of pool-water alkalinity, the care of sand beaches, and other details of pool and locker-room sanitation. Methods of testing the pool water for residual chlorine and for pH, or alkalinity, are described.

Copies can be obtained free on request to the publisher.

New Booklet Measures Spring Values for Special Duties

A new booklet which reports in detail on the value of five different metals for spring purposes under conditions which involve exposure to corrosion as well as to high and low temperatures and other severe service has been published by *The International Nickel Company, 67 Wall Street, New York, N. Y.*

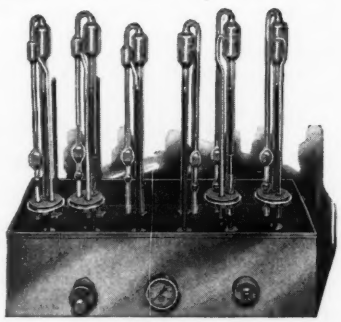
The five metals included are the two heat-treatable alloys, "Z" Nickel and "K" Monel, and Monel, Inconel, and malleable nickel. The booklet is well illustrated and contains technical data and tables on strength, stiffness, endurance, resistance to corrosion and corrosion fatigue, effects of high temperatures, and magnetic and electrical properties.

New Clay-Adams Centrifuge Catalog Now Available

The Clay-Adams Co., Inc., 44 East 23 Street, New York, have just issued their new 16-page Catalog No. 111, printed in two colors, featuring their entire Centrifuge line. This catalog will be of interest to every person concerned with the use of centrifuges. All models are illustrated, completely described and the prices given. Of particular interest is the new Adams Safety-Head Angle Centrifuge that gives a speed of approximately 5000 R.P.M. on direct current with six 15-ml. tubes loaded and 4200 R.P.M. on A.C. with the same load. If you have not received your copy you may obtain one by writing to the company on your department letterhead.

Cleaning Apparatus

This cleaning and drying apparatus primarily was designed for glass viscosimeters for determining kinematic viscosity. However this equipment is said to be adaptable for use in connection with the cleaning of other types of glassware such as test tubes, pipets, etc.



The tubes are placed over and supported by vertically extended metal capillary tubes through which the cleaning fluid is sprayed.

Drying is accomplished by passing air under pressure through the tubes. Pressure is regulated by means of special valves and the amount of pressure may be closely controlled and observed. Provision is made for first connecting the spray line to the vessel containing the cleaning liquid. Then by adjusting the valves, air is forced through the tubes. To prevent excessive use of solvent or cleaning fluid, a spring type valve is used which closes when the valve handle is released.

For further information write *C. J. Tagliabue Mfg. Co., Park and Nostrand Avenues, Brooklyn, New York.*

Klett Tested Reagents

The Klett Manufacturing Company has established a Chemical Department for the purpose of supplying the biochemical and clinical laboratory with those highly standardized reagents and solutions which are a necessity in modern colorimetric analysis. In a booklet entitled "Klett Tested Reagents," there is a list of reagents, with their costs, that can be supplied for testing the following substances: Sugar (Folin-Wu), iron and hemoglobin (Wong), oxyhemoglobin, creatinine, sugar (Benedict), non-protein nitrogen (Koch-McMeekin), uric acid (Folin), sugar (Folin-Malmros), urea (Karr), inorganic phosphate (Fiske-Subbarow), calcium (Roe-Kahn), sulfanilamide (Marshall-Litchfield), protein in cerebrospinal fluid, phenolsulfonephthalein (Rowntree-Geraghty), hemoglobin-acid hematin, bilirubin (Malloy-Evelyn), cholesterol (Bloor-Pelkan-Allen), vitamin C (Mindlin-Butler), icterus index (Schales), androsterone (Sachs-Kurzrok), albumin and globulin in serum (Looney-Walsh), iron in serum (Schales).

It is stated that reagents for procedures other than those listed above can be obtained on order. In these cases also, the solutions are said to be carefully standardized, to ensure satisfactory performance in the analysis.

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